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# FOREST AND RANGE INSECT, WEED, DISEASE AND VERTEBRATE PEST MANUAL

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Forest and range insect, weed, disease a
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# PREFACE

This manual is designed to provide commercial and government applicators detailed information concerning the recognition, biology and management of major insect, weed, disease and vertebrate pests of forest stands and rangeland. Specific control methods have been discussed when applicable.

Chemical trade names have been used for purposes of simplification, however, no indorsement of specific products is intended, nor is criticism implied of similar products or equipment that is not mentioned.

We wish to acknowledge the help of personnel of the Environmental Management Division, Montana Department of Agriculture and of the U.S. Forest Service, Missoula, Montana in preparing this manual.

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# SECTION I

# INSECT PESTS OF FOREST TREES

## CHAPTER I

## INSECT STRUCTURE AND CLASSIFICATION

Insects represent one of the largest and most diverse groups in the Animal Kingdom. While less than one percent of the over one million insect species inhabiting the earth can be considered pests, and an even smaller percentage pests of forest trees, these few rank with fire and disease as the three most destructive agents operating in the forest. Harmful insects are encountered in all phases of forest operations from seed production, planting, growing and harvesting of timber to the handling and protection of manufactured wood products. Insect pests through their injurious feeding habits also affect forest management areas such as recreational sites, watersheds, fish and wildlife. A variety of insect pests are working in the forest environment and represent a constant steady drain on timber production. Only a few species periodically reach epidemic levels resulting in widespread tree mortality.

It is difficult to determine the true economic impact of forest insect pest infestations because the affects of fires, disease, and insect feeding are often interrelated and not easily distinguished. Insect-killed timber is often salvaged, thus somewhat reducing the loss. Insect feeding results in reduced growth rate, tree quality and stand stocking, all factors very difficult to measure. Reduction in esthetic qualities of the forest due to insect infestation is equally difficult to describe in terms of dollars. One attempt by the U.S. Forest Service to measure insect pest impact in 1952 for the western states and Alaska estimated losses due to direct tree mortality, reduction in growth rate and losses to young plantings to be 13.6 billion fbm.

The wide ranging impact of insect pests on the forest environment demands that the forester be familiar with the appearance and characteristics of those species common to the region. A study of forest insects must begin with a general understanding of insect structure, function and classification.

### Insect Structure

Insects are in the group of animals called invertebrates, meaning they are without a backbone.

Insects have an outer case or skeleton called an exoskeleton. The following characteristics also distinguish insects from other animals:

1. Three body regions - head, thorax and abdomen.
2. Three pair of legs located on the thorax or middle segment.
3. One or two pair of wings also arising from the thorax (some insects have no wings).
4. One pair of antennae.

The drawing of a typical grasshopper below will help you visualize the location of the various structures.

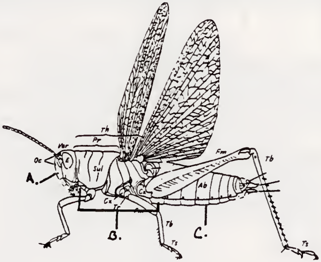


Figure 1. Typical insect structure.
A. Head B. Thorax C. Abdomen

A closer examination of the insect's three body regions will further aid in their recognition.

Head

The eyes (compound and/or simple), the antennae and the mouthparts are located on the head. The characteristics of the mouthparts and the antennae are useful in insect identification. An understanding of the mouthparts and feeding habits of insects can be helpful in selecting an effective control measure. Insect mouthparts are of two general types, chewing and sucking.

Insects with chewing type mouthparts move their mandibles, or jaws, in a sideways motion.

Insects with chewing mouthparts include the adult beetles, ants, bees, wasps, flies, dragon and damsel flies, grasshoppers, and crickets. Immature insects such as caterpillars, fly maggots, and beetle larvae also have chewing mouthparts.

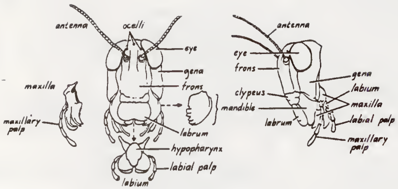


Figure 2. Mouthparts of typical chewing insect.

Sucking type mouthparts are highly modified. Insects with this type mouth structure cannot chew their food. Sucking mouthparts are in the form of a somewhat elongated beak through which food is sucked. This type mouth structure may be further modified to be:

1. Piercing-sucking as in the mosquitoes, true bugs and aphids.
2. Lapping-sponging as in the housefly.
3. Rasping-sucking as in the thrips.
4. Tube-like as in the moth and butterflies.

Insects with sucking mouthparts include the adult sucking lice, flies, mosquitoes, true bugs, aphids, scale insects, leafhoppers, moths and butterflies, fleas, and thrips.

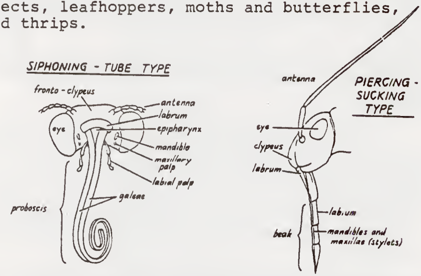


Figure 3. Major variations of sucking mouthparts of insects.
A. Siphoning - butterfly
B. Piercing sucking - aphids, bugs.

## Thorax

The thorax is the middle region of the insect body and is divided into three segments. One pair of jointed legs is attached to each of these segments. The legs are often greatly modified in different insect species. They may vary from thin and delicate such as those on a butterfly to thick and powerful for running or grasping prey such as the front legs of a praying mantis. The wings, when present, are also attached to the thorax. Characteristics of the legs and wings are often useful in insect identification.

### Abdomen

The insect abdomen is composed of up to eleven segments. The abdomen usually contains the external reproductive structures and excretory openings. Depending upon the species, the abdomen may have various types of ornamentations; some important for the insects physiology or protection and others with no apparent purpose.

## Insect Development

All insects develop from eggs, most after the eggs have been laid. A few insects develop from eggs within the body of the female and are born alive. Insect eggs very widely in size and shape. They are usually laid in protected locations that afford the young good conditions for survival.

After hatching, insects develop by passing through a series of growth stages. The size of an insect is restricted by its hard outer exoskeleton. Each new growth stage involves shedding the old exoskeleton and forming a new one. This shedding process is called molting. The insect stage between molts is called the instar.

As young insects progress towards adulthood, they may change not only in size but also in form. Metamorphosis describes the process of changing from egg to adult. All insects do not progress through the same series of changes. Some insects, like grasshoppers, change very little in appearance from the newly hatched young to the full grown adult. Other insects, like the moths and butterflies, undergo a drastic change in size and appearance, the young seldom resembling the adult form.

There are two general types of metamorphosis in insects:

Simple metamorphosis involves 3 stages, during which the wings (if any) develop externally.

Egg Stage: Adults lay eggs during warm periods of the year. Depending on temperature and moisture, the eggs may overwinter and hatch in the spring.

Nymphs: All immature stages of these insects are called nymphs. They look much like the adult but are of a smaller size. Nymphs (naiads if they develop in water) grow by shedding their skin and advancing through a series of instars to the adult form. If wings are present, they are not fully developed until the last molt is complete.

Adults: Adults are fully developed after the last nymphal molt. During this stage mating and egg laying takes place and the life cycle is repeated. Adults may or may not feed.

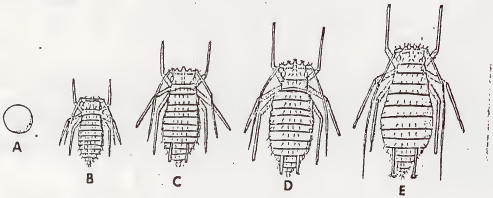


Figure 4. Example of simple metamorphosis. The aphid A egg; B, C, D nymphs; E adult.

Complete metamorphosis involves 4 growth stages and wing development is internal.

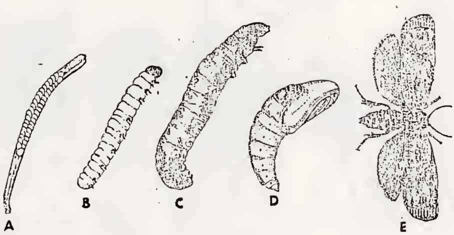


Figure 5. Complete metamorphosis - moth
A eggs; B, C larvae; D pupa; E adult.

| | |
|---|---|
| Egg stage: | The same as simple metamorphosis. |
| Larvae: | The newly hatched individuals are called larvae (larva, singular). They may be caterpillars, grubs, maggots, worms. Insects in this stage of development seldom resemble the adult. They are voracious feeders, rapidly molting and advancing through several instars. |
| Pupa: | The last larval instar develops into the pupa or resting stage. During this time, the insect changes from larva to adult within the confines of a cocoon or pupal case. The last molt occurs at the end of the pupal stage. |
| Adult: | Ultimately, the adult emerges from the pupa. After becoming sexually mature, mating occurs followed by egg laying. Adults may be short lived or, in a few instances, remain active for several years. Adults may or may not feed. |

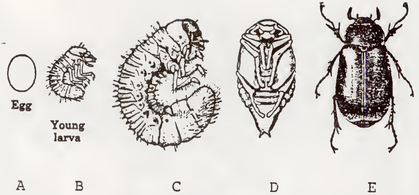


Figure 6. Complete metamorphosis - beetle.
A egg; B, C larvae; D pupa; E adult.

## Insect Classification

A systematic study of the several million plants and animals in the world demands some methods of arranging them in groups. Although there are several ways to classify living things, a standard method based on structural parts has been adopted by scientists worldwide. Under this system, the animal kingdom is divided into a dozen or so major groups called phyla. Ten of the more important phyla are listed in Table 1.

Table 1. Ten major phyla of the animal kingdom.

Invertebrates

1. Protozoa - single-celled animals; amoeba
2. Porifera - sponges
3. Coelenterata - jellyfish, corals
4. Platyhelminthes - flatworms, trichina
5. Nemathelminthes - roundworms
6. Mollusca - snails, slugs, clams
7. Echinodermata - starfish, sea cucumbers
8. Annelida - segmented worms, earthworms, leeches
9. Arthropoda - insects, spiders, crayfish, millipedes

Vertebrates

10. Chordata - fish, amphibians, reptiles, birds, mammals

This manual is concerned with animals primarily in the phylum Arthropoda and Mollusca. Each phylum is further divided into Classes, Orders, Families, Species. Each lower level in this classification scheme more precisely describes a particular animal. Using the common housefly as an example, the classification would be as follows:

Kingdom - Animal
Phylum - Arthropoda
Class - Insecta
Order - Diptera
Family - Muscidae
Genus - Musca
Species - Domestica

Common names of insects often vary for one species from one locale to another. To avoid much of this confusion, a systematic and standardized arrangement of scientific names has been developed. The name of each insect consists of the Order, Family, and Genus which are capitalized, followed by the Species and Sub-species name when applicable. The name of the person who described the species appears last. The genus and species name are written in italics and are underlined. A shortened form of the complete scientific name consists of the genus and species.

Examples: Common housefly
Full Scientific Name:
Diptera: Muscidae Musca domestica Linnaeus
Shortened Scientific Name:
Musca domestica Linnaeus

## Insect Recognition

There are approximately 26 orders of insects. This manual will deal only with those orders containing species injurious to forest trees, forest nursery plantings, milled wood products, shelterbelts and range plants. Eight important orders are described below.

Coleoptera - beetles. Adults usually have two pair of wings (front pair hard and leathery); chewing mouthparts; complete metamorphosis. Larvae are often called grubs. They are soft bodied and may be legged or legless. Grubs have chewing mouthparts. Exapmles: Colorado potato beetle, timber beetles, bark beetles, white pine weevil.

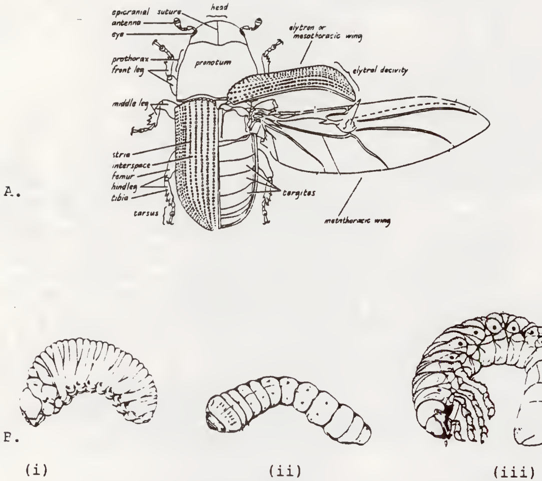


Figure 7. External anatomy of Coleoptera (beetles)
A. Adult B. Common larval types; (i) bark beetles
(ii) roundheaded wood borer (iii) June beetle.

Lepidoptera - butterflies and moths. Adults have two pair of wings; sucking mouthparts; complete metamorphosis. Immature forms (caterpillars) have chewing mouthparts. Some are destructive pests of crops, forests and fabrics. Examples: loopers, cutworms, sawflies, spruce budworm, Douglas-fir tussock moth.

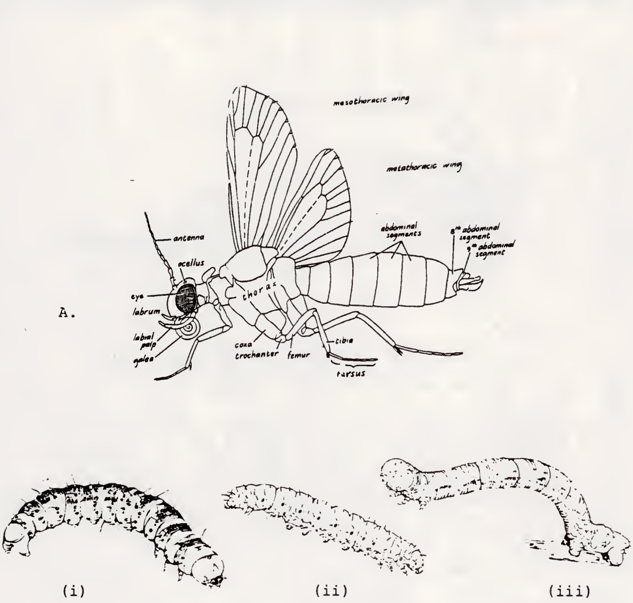


Figure 8. External anatomy of Lepidoptera (butterflies and moths)
A. Adult B. Common larval types (i) leafroller (ii) cutworm-armyworm (iii) looper

Hymenoptera - ants, bees and wasps. Adults characterized by two pair of wings (except worker ants); chewing mouthparts; complete metamorphosis. This order contains beneficial species (pollinators and parasites) as well as those which cause economic damage and human concern. Examples: carpenter ants, pine sawflies gall wasps, seed chalcids.

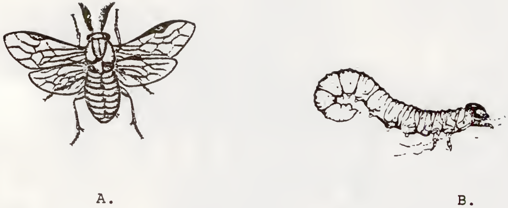


Figure 9. External anatomy of Hymenoptera (bees and wasps).
A. Adult sawfly B. Sawfly larvae.

Diptera - flies, mosquitoes, midges. Adults are two winged and possess piercing-sucking and lapping type mouthparts. Diptera develop by complete metamorphosis. Larvae are often called maggots and are typified by being soft-bodied, legless and headless. Larvae may develop in organic matter, water, or within plant tissues as leaf miners. Examples: biting midges, black files, gall midges.

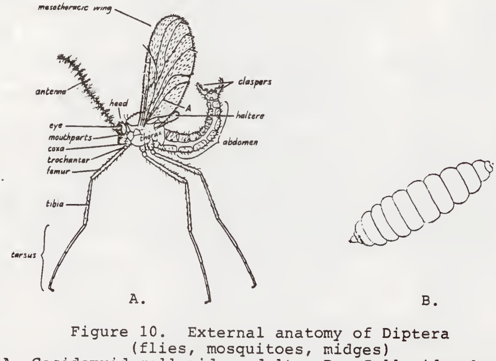


Figure 10. External anatomy of Diptera (flies, mosquitoes, midges)
A. Cecidomyid gall midge adult B. Gall midge larva

Homoptera - aphids, scales, planthoppers, leafhoppers. Adults may be winged (two pair) or wingless; sucking mouthparts, simple metamorphosis. The Homoptera are a large and diverse group of sap sucking insects. Several are important forest pests. Examples: pine leaf chermid, pine needle scale, pine bark aphid, Cooley spruce gall aphid.

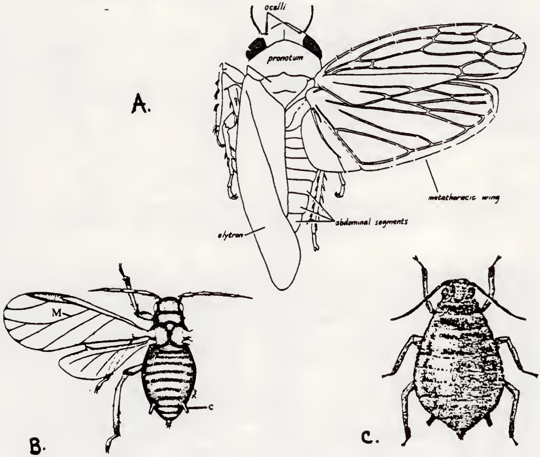


Figure 11. Representatives of Homoptera.
A. Adult leafhopper B, C. Winged and wingless forms of an aphid.

Hemiptera - "true" bugs. Members of this order have two pair of wings; sucking type mouthparts; simple metamorphosis. This order is similar to the Homoptera and are distinguished primarily by differences in wing structure. This order includes both injurious and beneficial species. Injurious species suck plant juices from grasses, twigs, leaves, seeds. Beneficial species act as predators attacking pest species of this order and others. Examples: black grass bug, minute pirate bug, lygus bug, boxelder bug, conifer seed bug.

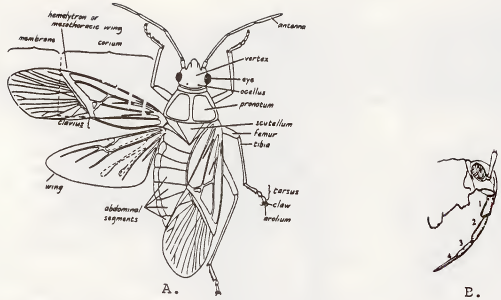


Figure 12. Hemiptera: Typical external anatomy. A. Adult "bug" B. Closeup of beak-like sucking mouthparts.

Orthoptera - cockroaches, grasshoppers, crickets and mantids. May be winged or wingless. Winged forms have two pair of wings; chewing mouthparts; simple metamorphosis. Many members of this order are important plant pests. Examples: lesser migratory grasshopper, mormon cricket.

Isoptera - termites. Isoptera are social insects living in colonies. Both winged and wingless forms occur in a colony. Termites have chewing mouthparts, and follow simple metamorphosis. This order may be highly destructive to wooden structures which are not protected.

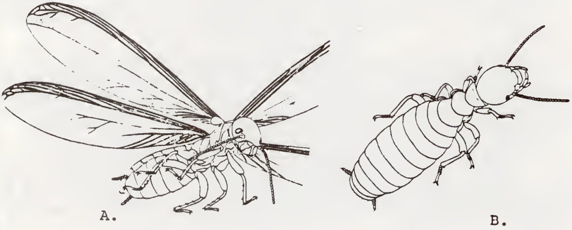


Figure 13. Form differences of termites. A. Winged reproductive B. Wingless worker.

## Insect Allies

There are invertebrates, other than insects, which are also pests of forest and range plants. Of the Classes other than Insecta within the Phylum Arthropoda, only the Arachnida (spiders, mites and ticks) are of importance to the forester or range specialist. Arachnids differ from insects in that they lack antennae, true jaws and compound eyes. They have four pairs of legs and only two body regions. The Class Arachnida is divided into a number of Orders, two of which will be discussed in this manual.

Order Araneida - Spiders. Spiders are generally considered beneficial residents of the forest and range. While two notable species, the black widow and the brown recluse are venomous to man, the majority are predaceous on a wide range of forest and range insect pests. Those spiders which build webs trap many flying insects and some larvae which fall from trees. Those species not dependent upon webs for hunting move about more freely and encounter concentrations of various insect pests. Further study is required to accurately measure the influence of spiders as regulators of forest and range pests.

Order Acari - Mites and ticks. There are nine sub-orders in this large and diverse group, several of which are important in the forest. Some mites are injurous to forest, ornamantal and selterbelt plantings. Their sucking feeding habits often cause distortion of leaves and stems. Other mites are beneficial parasites and predators of other pests. Ticks are generally not important to the forester or range specialist. While one tick species, the common wood tick, is a vector of a potentially serious disease in man, most ticks are important as disease vectors attacking wild and domestic animals.

### Development and Biology of Arachnids

Spiders - The body of a spider is divided into two regions; the cephalothorax and the abdomen. The unsegmented abdomen is attached to the cephalothorax by a narrow pedicel. The eyes, mouthparts and legs are located on the cephalothorax while the abdomen bears the genital structures, spiracles, anus and spinnerets. The eyes are simple and are located at the front of the cephalothorax. Spiders generally have eight eyes (some fewer) and the number and arrangement of the eyes is useful in distinguishing different families. The chelicerae or fangs of the spider are located at the anterior end of the cephalothorax and are directed downward. The ducts of the spider's poison glands open near the tips of the chelicerae. The seven segmented legs usually bear two or three claws at their apex.

The spinnerets consist of about six fingerlike structures located on the ventral side of the abdominal posterior. At the tip of each spinneret are many small spinning tubes from which the silk emerges. Spider silk is used in the construction of webs and/or in nest building.

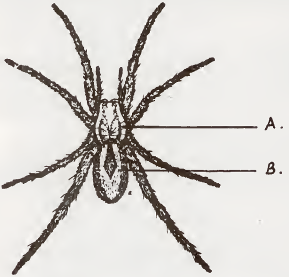


Figure 14. External anatomy of a typical spider. A. cephalothorax B. abdomen.

Spiders develop by a form of simple metamorphosis, although they change very little in appearance from the time of hatching until they reach adulthood. Spiders generally lay their eggs in a silken sac attached to leaves, bark or other structures. Eggs generally hatch shortly after they are laid. If the eggs are laid in the fall, the young spiders may overwinter in the case. The two sexes of spiders can often be distinguished by a difference in size or coloration. In many cases, mating is followed by the female's killing of the male. Webs of the web spinning varieties may vary considerably and are distinctive for a particular species.

Mites - Mites are generally quite small eight-legged animals that resemble spiders. They differ from spiders in that the two body regions are broadly joined together rather than being connected by a pedicel.

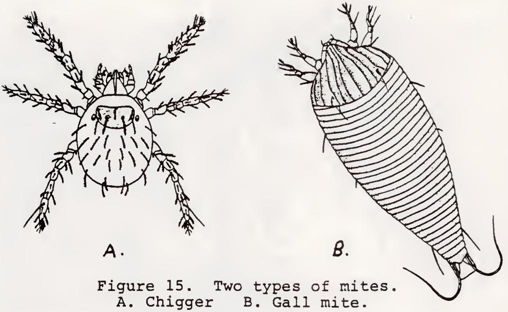


Figure 15. Two types of mites.
A. Chigger B. Gall mite.

Mites undergo a form of simple metamorphosis. Eggs may be deposited or in few species, live young are deposited. The first immature stage (larva) usually has six legs, the forth pair developing after the first molt. There may be one or as many as four active nymphal stages.

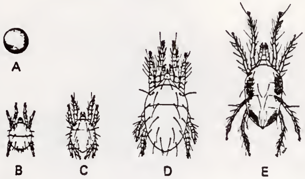


Figure 16. Development of a mite.
A. Egg B. First instar or larva C, D. Nymphs
E. Adult female.

There are several important sub-orders of mites that are important in forest and range environments.

Mesostigmata - This is a large group of predaceous and parasitic mites characterized by having hardened shields or plates above and below. Some species in this group are predaceous on bark beetles while others attack plant feeding mites.

Prostigmata - This group contains parasitic, predaceous scavenging and plant feeding species. The best known mites in this group are the spider mites or red mites (Tertranychidae). Spider mites feed on a wide variety of forest and ornamental plants and sometimes occur in tremendous numbers. Eggs laid on the plant during the summer generally hatch in four or five days. Four instars are completed and growth from egg to adult requires about three weeks. The spruce spider mite which attacks spruce and Douglas-fir is the only species in this group that has been rated as a serious forest pest. However, other species are common and sometimes serious pests of conifer and broad-leaved ornamentals, especially under dry hot conditions.

Gall mites (Eriophyiidae) are extremely tiny in size. They have only two pairs of legs and are elongate. Gall mites feed almost predominantly on perennial plants and are highly selective of hosts, seldom attacking species in more than one genus. Development from egg to adult takes about 2 weeks. Several species of gall mites attack the needles of pines, foliage, buds and twigs of several conifer species in the west.

Heterostigmata - Mites in this group are soft-bodied with minute mouthparts and are often found preying on or living with forest insects, especially bark beetles.

## Insect Field Identification

Proper identification of the pest is essential prior to selection of a control method. There are various identification aids available such as pictures, written descriptions and keys. Since insects are small, the forester or range specialist should carry a good quality 10X hand lens to examine specimens encountered for important characters helpful in identification. The following descriptive key (Table 2.) will be helpful in separating the principal orders discussed in this manual.

Table 2. Insect identification - most common economic orders

| ORDER | STAGE | MOUTHPARTS | LEGS | WINGS | EYES |
|---|---|---|---|---|---|
| Coleoptera (beetles) | Adult | Chewing | 3 pair on thorax | 2 pair:<br>1 hardened<br>1 membranous | Compounds eyes only |
| | Larvae (immature) | Chewing | Thorax only (occasionally legless) | None | Simple eyes only; one to six pairs of ocelli |
| Diptera (flies) | Adult | Lapping, spinging, or piercing | 3 pair on thorax | 1 pair membranous,<br>1 pair halteres (tiny stubs that are reduced wings) | Compound and simple. Ocelli three arranged in triangle. |
| | Larvae (immature) | Chewing, (may be mouth hooks) | None | None | Absent in the maggot forms of higher flies |
| Hemiptera (true bugs) | Adult | Sucking | 3 pair thorax | 2 pair:<br>outer leathery with membranous tips, inner membranous | Compound and simple. |
| | Nymphs (immature) | Sucking | 3 pair thorax | None | Compound and simple. |
| Homoptera (aphids, scales, etc.) | Adult | Sucking | 3 pair thorax; (scales may be legless) | 2 pair:<br>in some cases membranous | Compound and simple. |
| | Nymphs (immature) | Sucking | 3 pair thorax | None | Compound and simple. |
| Hymenoptera (bees, wasps) | Adult | Chewing or occasionally lapping | 3 pair thorax | 2 pair, both membranous | Compound and simple. Ocelli three, arranged in triangle. |
| | Larvae (immature) | Chewing | Thoracic; also abdominal in sawflies but lacking crochets | None | Simple eyes or occeli only. |
| Lepidoptera (butterflies, moths) | Adult | Sucking | 3 pair thorax | 2 pair; membranous but covered by small scales | Compound and simple, usually 2 ocelli. |
| | Larvae (immature) | Chewing | Thoracic; abdominal with crochets (hooks) | None | Simple eyes only. Ocelli arranged in 2-6 pairs. |

Another method of insect recognition useful to the forester involves an examination of the damage done by the pest. Feeding damage patterns are often characteristic of a group of pests. In some cases, even certain species can be identified by the feeding damage they cause. Forest insects damage trees and shrubs in a variety of ways. Adults of some species may feed on foliage, twigs and buds. They may damage twigs by slitting the tender cambial layer and inserting their eggs. Adult bark beetles bore into the bark and construct a series of tunnels, thus damaging the tree. Adult wood borers bore into the sapwood and, in some cases, into the heartwood. Usually, the greatest feeding damage is done by the larval and nymphal stages of the pests. The egg and pupal stages are never implicated in host damage.

Forest insects generally damage trees by chewing, sucking or gall forming. The majority of pests fall into the chewing category. In some species both the adult and larva are damaging while in pests such as the butterfly and moth defoliators, only the larva actually feeds. Aphids, scales and mites injure plants by inserting the slender mouthparts into stem or leaf tissue and sucking the plant juices. Some insects of this type inject a toxin into the plant while feeding. The toxin alters plant growth at that point and may cause swellings (galls) or distortion of the plant tissue. Not only is feeding damage a good indicator of the insect pest types, but also it will provide information useful in selecting a control method. Table 3 describes common types of feeding damage and the pest groups capable of causing the damage.

## Table 3. Types of insect injury
(Dependent upon mouthparts)

### Damage from chewing insects

*Defoliators* - Those pests which chew portions of leaves or stems, stripping or chewing the foliage of plants. Examples: leaf beetles, caterpillars, cutworms, grasshoppers, sawfly larvae.

*Borers* - Those pests with chewing mouthparts which bore into stems, tree boles, wood products. Examples: mountain pine beetle, white pine weevil, golden buprestid, powder post beetles.

*Leaf Miners* - Those pests that bore into and then tunnel in between epidermal layers of leaves. Example: birch skeletonizer, lilac leaf miner, pine needle sheath miner.

### Damage from piercing and sucking insects

*Distorting plant growth* - Those pests that cause leaves, fruit or stems to wilt, curl, or become distorted. May be caused by aphids, mites, midges, psyllids, sawflies, and wasps. Examples: Aphid injury, cone gall on spruce, Douglas-fir, cone midge, chalcid galls on pine.

*Cause stippling effect to leaves* - Those pests who may leave many small discolored spots on the leaves which eventually turn yellow. Example: spider mite injury.

# CHAPTER II

## PRINCIPLES OF INSECT CONTROL

### Introduction

Insect populations are held in check by a number of limiting factors including weather, host availability, host acceptibility, parasites, predators, and disease. These factors balance the tremendous reproductive capacity of insects. Those insects that manage to escape their enemies are few in number and under "natural" conditions feed and live on their hosts without inflicting economic injury. The damage done by these endemic populations is negligible and greatly outweighed by the annual growth of the stand as a whole. While this balance is indeed delicate, it may continue for many years in a particular stand. However, the forces of natural control may diminish occasionally. The pest's parasites or predators may be reduced in numbers one season. The resistance or vigor of the stand may be reduced through some other natural factor such as fire, drought, wind, etc. Under these conditions, a pest species is able to make use of its adaptability and high reproductive capacity and a pest outbreak or epidemic develops.

A multi-age forest stand at some stage of succession may be better able to withstand periodic pest outbreaks. A mixture of tree species and different age classes will greatly limit the pest's preferred food supply. However, tree plantation stands are manipulated by man through extensive harvesting operations or may be highly susceptible to pest outbreaks. Like an agricultural planting, forest stands of this type offer a relatively unlimited food supply to the pest. Outbreaks quickly become widespread and are difficult if not impossible to stop. Prevention when practicable is a far better approach.

Because of the highly dynamic nature of forest insect populations and the forest itself, it is essential that the forester be aware of the signs and symptoms of a developing pest problem. The basis of forest insect control is prevention. There are a number of "Steps to Pest Control" that the forester should keep in mind.

1. Detection - Always be on the lookout for troublesome pests in the stand. Early detection of a pest hot spot can direct control methods to a more confined area thus preventing buildup and spread of the problem. Aerial surveys combined with ground truth

cruises are common methods of pest detection in the forest. Random ground surveys are commonly used on range. However, an alert forester or range specialist can often times detect a early stage pest problem before it can be detected through conventional survey methods.

2. Identification - A pest must be accurately identified before it can be effectively controlled. In some cases the most obvious insect in an area may not be the one causing the damage. Knowledge of the pest's seasonal cycles is important in order to select the most effective type of treatment and the best time for application. Ill timed treatments are ineffective, wasteful, and needlessly hazardous to the environment. Collect and submit samples of the apparent pest to the local U.S. Forest Service office, the Montana Department of Agriculture, Montana Division of Forestry, or the Cooperative Extension Service.

3. Economic Significance - Pest control activities have both an economic and environmental impact on the forest, range, and the respective land owners. Treatments for forest or range pests should be made only when the threat of real economic damage outweighs the total cost and impact of treatment. This treatment threshold or economic threshold is often very difficult to determine under forest conditions. Many factors must be weighed. What are the estimates of retarded growth or tree mortality if the infestation were allowed to proceed unchecked? How much timber can be salvaged? What control alternatives are available? What are the risks to the land owner(s)?

4. Selection of Methods - Coincident with determining economic impact of the infestation, the available methods of control are considered. When several alternatives are available, the method that will be the most practical, effective, economical and the least hazardous to the environment should be selected. Control alternatives are often quite limited in the forest situation and the "no action" alternative must always be considered.

5. Application - Whatever the control methods selected, they must be applied in a

conscientious manner to be effective and safe. Should the method be a chemical insecticide, the application must be done at the proper time, under the right climatic conditions, at the proper rate and with the right equipment. Chemical formulations, size of treatment area and environmental concerns will bear on the selection of equipment. The application equipment must be in good working order and correctly calibrated for the rate and type of application required. Application must be done only by competent individuals under the guidance of a person specifically trained in the methods of pesticide application.

6. Evaluation - The results of the treatment must be evaluated and recorded. This can be done in several ways; insect counts before and after treatment, comparative damage ratings, yield or growth measurements, etc. Records of treatment performance provide the basis for gaining from past experiences. It is very important to keep a record of pre-and post-treatment pest levels, type of treatment method, chemical applications including rates of chemical and carrier, tree species treated, etc.

# CHAPTER III

## INSECT CONTROL TACTICS

Once a decision has been made to implement some type of control practice to halt an ongoing insect infestation or to prevent the buildup and spread of a pest, close consideration of available control tactics or "tools" should be made. In a general sense, outbreak prevention or control of forest insect pests falls into two categories.

1. Direct control tactics - designed to curb outbreaks inprogress for the purpose of reducing pest levels and protecting foliage.
2. Indirect or long-term tactics - including silvicultural, biological or other methods designed to utilize and augment natural control factors operating in the stand for long-term protection.

Selected control alternatives in the above categories need not be an either/or process. While both categories may fit well together in some situations, the two are usually not equally practical or pertinent for all insect pests. Each of the above categories contain several specific control methods.

### Direct Control Tactics

#### Physical/Mechanical Methods

1. Manipulation of Environmental Conditions - Temperature and moisture play important roles in the growth and development of insects. Often only slight variations on one or both of these factors will result in a decrease of insect vigor, leading ultimately to a reduction or cessation of population growth. Of course, extreme changes in temperature may lead directly to insect mortality. Burning of infested wood, although time consuming, is a tried and true method of reducing bark beetle populations. Burning of infested wood debirs around mills and factories or exposing lumber to kiln temperatures is an effective means of reducing powder post beetle infestations. Exposing thin-barked trees and slash to direct sunlight will hasten drying and will kill beetles infesting the exposed surface. This method does require turning the wood to expose all surfaces and because of the manpower requirement, is not applicable to large areas.

Reduction of moisture content of wood will make it less favorable for insect habitation and may be appropriate in some situations. Conversely, storage of timber in log ponds or lakes near the mill will also prevent insect infestation to a degree. Destruction of soil tunnels constructed by termites will expose them to unfavorable moisture conditions leading to the destruction of at least part of the colony.

2. Destruction of Habitat - This method is related to environmental modification described above. Peeling the bark from slash and logs will destroy the immature stages of bark beetles and will aid in drying the wood, thus making it undesirable for other wood destroying pests. Destruction of termite soil tunnels as mentioned above will reduce colony strength.

3. Trapping and Destroying - This method involves utilizing susceptible host material, chemical or physical attractants (lights, sounds, etc.) to draw pest species into a confined space where they can be easily destroyed. The trap tree method has been used repeatedly to reduce bark beetle populations.

4. Physical Barriers - Adhesive materials, screens, shelters, protective or repellent coatings are examples of physical barriers that can be useful in forest, nursery or plantation situations as preventative devices.

5. Handpicking, Jarring, Shaking, Mechanical Collection - These methods have limited application to small plantings. This method is too manpower intensive for wide application but in the case of a forest nursery or plantation, handpicking and destroying the pest as it is encountered may be more economical than chemical treatment or some other method.

## Salvage Logging

Salvage logging has long been a standard forest management practice aimed principally at removing dead and damaged trees that still have market value. Salvage removal is commonly used in bark beetle infestations to prevent spread to healthy uninfested stands. Salvage logging is usually best suited to roaded areas where access is not a problem. However, the advent of helicopter and balloon logging have made salvage logging a viable alternative for bark beetle management in otherwise untouchable stands.

When salvage logging is considered for prevention of bark beetle spread, time frames are critical. If the area is too large, beetles will fly from infested trees long before salvage operations are complete. The tree species infested will have a bearing on the amount of time available for salvage operations. Species such as lodgepole and white pine as well as Engleman spruce and white fir can normally be economically salvaged for a year after infestation. More durable species such as Douglas-fir may remain economically salvageable for several years.

## Chemical Control

Insecticides are an established means of insect control. Their use can often provide a rapid, efficient, economical, and dependable means of pest control. Used properly, insecticides are an ecologically sound tool, invaluable to a pest management program.

Two approaches may be taken to reduce the major disadvantages of present day insecticides.

Physiological selectivity - By developing insecticides with a narrower range of biological activity, the effects on nontarget species can be appreciable reduced. These products are in sharp contrast to the present arsenal of broad-spectrum products.

Ecological selectivity - Altering the use patterns of many presently available insecticides can greatly reduce their adverse environmental effects. This approach is much less expensive and time consuming than the development of physiologically selective compounds. Some areas that can be altered to enhance insecticidal ecological selectivity are:

1. Timing of application - The proper timing of insecticide treatments will result in more effective control of the pest while using less insecticides and causing the least adverse effects on beneficial species. Timing involves:
    a. Treatments only when pest levels warrant, and
    b. Making the treatment to the most susceptible life stage of the pest.
2. Placement of the Insecticide - More effective delivery of the insecticide to the target will reduce the amount of chemical needed for

control and reduce the effect of the treatment on non-target species.

Seed treatment in nurseries of various tree species with a suitable insecticide, for example, may be as effective at controlling wireworms and other seedling pests as side banding or broadcast application. Seed treatment requires much less chemical and only effects those pests coming in contact with the seed.

3. Application Equipment - Utilizing the right equipment, correctly calibrated, will ensure that more chemical reaches the target area. Improved equipment design can be a major factor in reducing the majority of the adverse effects of insecticidal treatments.

4. Insecticide Formulation - The effectiveness of an insecticide can vary with the manner in which it is formulated. Different formulations may be more effective in certain treatment situations. Baits, low volume, and ultra low volume formulations have a potential for increasing control effectiveness while reducing adverse environmental effects.

Unlike agricultural producers, foresters are fortunate in that they seldom have to make routine applications of chemical insecticides. However, in times of pest outbreaks, chemical insecticides may offer the only means of curtailing the spread and preventing further damage. Chemical insecticides still offer the most effective means of reducing outbreaks of forest defoliators and grasshoppers on rangeland. The development of aerial spraying over the past 30 years has reportedly prevented millions of dollars of timber loss from such pests as spruce budworm, Douglas-fir tussock moth and hemlock looper.

Insecticides do have limitations. Their direct and indirect adverse effects to non-target organisms and the environment is probably their principal disadvantage. Insecticides also tend to select resistant traits in a pest population.

The development of resistance to some pesticides by insect pests has been one unfortunate result of "cure all" applications of pesticides. Resistance is a highly selective process that separates out those individuals in every pest population possessing the ability to detoxify a chemical and render it harmless or to escape its effects through a behavioral change. Resistance in this context is an example of evolution in action. All populations have the ability to develop resistance to poisons, diseases or other adverse effects. Insect pests are no different.

Economics of pesticide application have contributed to the development of insect resistance to pesticides by dictating that application rates be sufficient to kill almost, but not all, of a pest population. Those individuals which survive pesticide treatment are consequently the most "resistant" forms. Their resistant qualities are then passed on to future generations resulting eventually in an entire population resistant to a particular pesticide or group of pesticides. For instance, application of DDT to control houseflies has resulted in the unnatural selection of housefly strains which require 10,000 times the dosage of DDT required to kill their predecessors. This scale of application is of course uneconomical, impractical and hazardous.

### Autocidal Control

This method involves the genetic or mechanical (by radiation) manipulation of a pest population to control their numbers. The sterile male technique involving the mass sterilization of thousands of laboratory reared males of a pest species and their subsequent introduction into the natural population has been used successfully. This method, however, has limited application because of its cost. Chemically altering the genetic composition of a species is receiving much research attention. Further field testing of this method is required.

### Insect Growth Regulators

Like plants, insect growth and development are regulated by hormones. Molting and development from one growth stage to another can be altered by regulation of the amount of the respective hormone given to an insect. The application of juvenile hormone to a pest population is receiving considerable research at this time. One chemical growth regulator in particular, Dimilin, has been successfully field tested on the gypst moth. Future use of this chemical and similar products is encouraging.

### Pheromones

Pheromones are chemical materials produced and released by the female and/or male of an insect species for the purpose of communication. Some pheromones serve as tags or markers to direct members of the same species to food sources, or away from oviposition sites. Other pheromones called sex pheromones elicit aggregation and mating behavior. In recent years the synthesis of many of these pheromones has added a new dimension to insect monitoring and control. Incorporated in attractant traps of various designs, pheromones provide a means for detecting the presence of particular pest species and determining economic population levels. Incorporated in specially designed chips or laminated strips and applied over large areas by airplane, pheromones offer a means of pest population reduction by confusing normal mating behavior and thereby diminishing the number of successful matings.

## Indirect Control Tactics

### Silviculture Methods

This method involves bringing a forest stand under intensive management, thus making it possible to somewhat regulate conditions within the stand, rendering it less susceptible to insect attack. The age, species composition and vigor of the stand are interrelated factors affecting stand susceptible to insect attack. Silviculture management is designed to minimize insect losses throughout the rotation period of the stand, realizing that a healthy, thrifty forest is less likely to incur extensive insect damage. Avoidance of injury through fire, wind, flooding; aggressive stand sanitation through prompt clean up of slash and blow down; and selective harvesting techniques designed to regulate stand composition and density are all silvicultural techniques that can effectively lessen the chances of insect outbreak over the life of the stand.

Plantations lend themselves well to silvicultural management. Particular consideration of the growing site, adaptability of tree species to the site and tree spacing will all affect insect activity within the planting.

### Biological Control

Insect pests are adversely affected by their natural enemies. Parasites, predators, pathogens, adverse environmental factors, and population pressures act to hold most pest populations at sub-economic levels. Pests introduced to this country are usually not accompanied by their natural enemy complex, and once established, become very difficult to control.

Biological control, simply defined, is the deliberate use of natural enemies for the control of pest species. Biological control may involve:

1. Introduction of exotic parasites and predators - against introduced or native pest species.

2. Conservation of natural enemies - protecting those natural enemies already present in the pest's environment or modifying the pest's environment to allow for an increase of natural enemies.

3. Augmentation of parasites and predators - involving the mass rearing and periodic release of natural enemies already present in the pest's environment and proven to be effective control agents.

Biological control systems have three basic advantages over other forms of control.

1. Permanence - Once established, a biological control program is, for the most part, permanent. The system is self-perpetuating providing that natural enemies are able to become firmly established in the environment of the pest. Natural enemies are capable of continually adjusting to changes in pest population size.

2. Safety - Biological control programs have no harmful side effects, such as toxicity or environmental pollution and can be handled without hazard.

3. Economic - Because biological control systems are self-perpetuating, they are far more economical, once established, than the continuous application of pesticides.

Among the natural enemies of insects which may be employed in biological control systems are:

1. Predacious and parasitic arthropods
2. Predatory vertebrates
3. Nematode parasites
4. Protozoan diseases
5. Parasitic fungi
6. Bacterial diseases
7. Viral diseases

Examples of Biological Control:

1. The introduction of the Australian lady beetle or vedalia into California for control of the cottony cushion scale.

2. Introduction of hymenopteran parasites for control of the Citrophilus mealybug.

3. Introduction of *Agathis pumil* to control larch casebearer.

4. The use of polyhedrosis virus sprays to control Douglas-fir tussock moth.

5. The use of a bacterial pathogen, *Bacillus thuringiensis*, for control of several species of damaging caterpillars.

## Integrated Pest Management

Integrated Pest Management (IPM) involves using the best combination of available and suitable control techniques to reduce pest populations and maintain them below economically injurious levels.

The concept of integrated pest management (IPM), as known today, began approximately 25 years ago, although the procedures and philosophies have been practiced for hundreds of years. IPM is an ecological approach to pest control, a realization that all pest populations are affected by the interactions of their environment. IPM is based on the premise that it is economically unnecessary to rid a crop completely of a particular pest. Most crops can tolerate some level of pest activity without a significant reduction in yield or quality.

IPM strives to protect the natural enemies of the pest complex active in a particular crop or forest stand. The natural enemy complex is one of the most significant of the population limiting factors in a pest's environment and one of the most easily altered by man's manipulations.

Since the natural enemies require pests for their survival, sub-economic pest levels are encouraged. Natural enemies may be protected in a variety of sites within the stand. Should a chemical treatment be necessary, selection of a chemical that will only mildly affect the natural enemies while still reducing the pest population is preferred.

In practice, IPM, 1) assesses the pest population through the use of available monitoring methods to determine if a need for treatment exists; 2) selects the best combination of available control "tools" for the specific treatment need and; 3) accurately determines the proper timing of the specific treatment. The longer rotations of a forest environment make the weekly surveys common in agricultural IPM programs uneconomical and possibly unnecessary. At least yearly surveys of a particular stand are essential for early pest detection. Special monitoring of particular pest species in a buildup phase may be called for. Pheromone trapping for Douglas-fir tussock moth, spruce budworm, and bark beetles are examples. Forest plantations and nurseries are better adapted to an IPM monitoring program. Three or four surveys a season may be appropriate depending upon the pest history around the planting and the tree species involved.

Should a pest problem be encountered during a routine survey, additional inspections on a twice weekly basis may be called for to monitor the pest's rate of development. Information from several surveys is compiled and a judgement made concerning the need for treatment. With this approach, treatments are applied on an as needed basis rather than on a wholesale preventative schedule.

Silvicultural management can form the basis of an IPM program for forest plantings. Pest control or pest prevention then becomes an additional factor figured into the overall management plan for the stand. Such an approach allows and encourages the forester to be regularly considerate of the potential of insect pest outbreaks rather than handling them on an emergency basis as they occur. There are practical problems faced in integrating silvicultural, biological, chemical, and other control measures. The IPM approach to forest insect pests in still in the early stages of development.

# CHAPTER IV

# CHEMICAL CONTROL METHODS

## Introduction

The application of chemical insecticides remains one of the most effective and economical insect control strategies. While cultural, biological and integrated methods will increasingly provide effective alternatives, insecticides will continue as the basis for most pest management programs. It is important that the applicator and dealer alike have a strong understanding of the basic classification and characteristics of the insecticides they sell and apply.

## Insecticide Classification

Insecticides are just one of a large group of plant and animal control chemicals called pesticides. Insecticides, as the name implies, are chemicals especially developed to control insects.

Insecticides are generally classified by their chemical structure. There are are two large groups of insecticides: 1) inorganic, and 2) organic compouns. Each of these groups is further broken down.

### Inorganic Compounds

Derived from basic chemical elements.

Arsenicals - containing some form of arsenic; active as a stomach poison. Examples: lead arsenate, calcium arsenate

Fluorine Compounds -developed as more effective stomach poisons. Most of these compounds are no longer registered or seldom used. Examples: sodium fluosilicate

Sulfur Compounds - effective against mites and many suckinginsects as a contact poison. Examples: kolofog, sulfur

### Organic Compounds

This large chemical group consists of products with a structure based on the element carbon.

#### Natural Organic

Originating from plants or animals.

Botanicals - derived from plants; may act as a contact or stomach poison. Examples: rotenone, nicontine, ryania, pyrethrum

### Synthetic Organic

This group includes the most widely used chemical insecticides. They act primarily as contact poisons affecting the central nervous system of the pest.

Organochlorines - so named because of the presence of the element chlorine in their structure. Organochlorines generally exhibit long residual activity, a broad range of toxicity, and the tendency to accumulate in soil, water, plant and animal tissues. Many of the products in this group are no longer registered for use. Examples: DDT, Endrin, Chlordane, Toxaphene.

Organophosphates - characterized by containing phosphorus intheir chemical structure. These compoundshave a shorter residual life than organochlorines, are generally more acutely toxic to man, and are rapidly degraded by sunlight, heat and water.
Examples: Malathion, Parathion, Diazinon.

Dinitrophenols - effective as contact poisons for mites, aphids, scales; commonly applied as a dormant spray. Examples: Elgeton, DNOC.

Carbamates - similar to the organophosphatesnamed because they are derived from carbamic acid. The carbamates as a group are rapidly degraded in the environment. Several of these products are extremely toxic to man, while others have a low mammalian toxicity. Examples: Sevin, Baygon, Temik.

Oils - hydrocarbon compounds used as contact insecticides; particularly effective against the egg stages of various insects and mites.
Examples: Dormant oils, Superior (Supreme) oils.

### Specialized Insecticides

In addition to these insecticide groups based on chemical structure, there are several other specialized categories.

Compounds in this group are defined by their action or specialized make-up rather than by chemical structure alone.

Biologicals - specially formulated compounds of fungal, bacterial or viral organisms which act specifically on certain species or groups of insects. They may gain entry into the insect by ingestion or penetration of the body wall. Their highly specific nature and environmental safety make them very attractive. Examples: *Bacillus thuringiensis* (Dipel, B.T.), *Beauveria bassiana*, polyhedrosis virus.

*Attractants* - formulations used to attract insects to a favorable location for control. This group also include highly specialized attractants called *pheromones*. These compounds are synthetic mixtures similar to the chemicals released by the female of the species to attract the male. Pheromones are very useful in monitoring certain pest population levels. Examples: Disparlure, Codlelure.

*Repellents* - used to repel insects from man and domestic animals. Examples: Diethyl toluamide, Dimethyl phalate, Dibutyl phalate.

*Systemics* - a specialized group of insecticides that are absorbed into and circulated throughout the host; particularly useful in the control of sucking insects may be members of the organophosphate or carbamate groups. Examples: Metasystox, Disyston, Thimet.

*Fumigants* - these insecticides occur in liquid, gaseous, or solid form. Their active state is a gas. Fumigants are used to control insects in soil and confined spaces, such as grain elevators, box cars, etc. Fumigants are extremely hazardous to the applicator and should be handled only by trained personnel. For a more complete discussion of fumigants, refer to Montana Department of Agriculture Training Manual for Fumigation.

## Factors Affecting Insecticide Application

Insecticides may be used to 1) prevent, or 2) suppress an insect buildup. For most forest situations, preventative treatments made prior to any detection of a pest are not recommended. Because of the highly dynamic nature of insect populations, it is usually impossible to predict from one year to the next which insect pest, if any, will attack a particular stand or planting. A watchful eye can often provide the best warning of impending problems. Application of chemical insecticides on an "as needed" basis will reduce the cost of treatment, increase their effectiveness, and minimize the adverse environmental impact of the treatment.

Four principal factors will ultimately determine the overall effectiveness of insecticide applications.

1. Selection of the proper insecticide begins with correct identification of the pest. Chapters 1 and 5 provide an account of pests you may encounter. If you are unfamiliar with the insect, have it identified by a qualified entomologist or pest control consultant.

2. Timing the insecticide application to coincide with the most vulnerable stage of the insect pest is very important. Some applications are aimed at the egg or larval stage while others are intended to control the adults. An understanding of the life cycle of the insect is essential in determining the best time to apply the insecticide. Consult a good insect pest field guide, the local extension agent or pest control specialist.

3. Frequency of application - Preventive insecticide applications may require the use of a product with long residual toxicity. Due to the variety of situations requiring pest control operations (fields, forests, storage area, etc.), restrictions on residual insecticides may be quite stringent. Recurring pest problems may require more frequent applications of insecticides. Frequency of application is dependent on the treatment area, the insecticide employed, the recurrence of infestations, and the success obtained with the application.

4. Quality of application - Quite often the failure of a product to control a pest is related to the manner in which the chemical was applied. For most pest situations, it is critical to get the chemical to the plant region occupied by the pest. Selection of the proper equipment for a given treatment, proper calibration and maintenance of the equipment and proper operation of the equipment by trained personnel will greatly increase the effectiveness of the treatment.

## Methods of Insecticide Application

While standard methods of insecticide application by ground and air used in forestry are covered in detail elsewhere (Basic Pesticide Equipment Training Manual), there are a few techniques unique to forest pest situations that should be mentioned.

Hydraulic ground sprayers are useful in applying insecticides to plantation trees where truck or tractor access is not a problem. Applications to trees in sensitive areas such as recreational areas may also be made with hydraulic equipment operated at low to moderate pressure with the nozzel attached to a telescoping boom. This method is useful in applying materials for bark beetle control where it is important to drench the tree bole to the point of run-off.

Application to foliage for control of defoliators and some sucking insects is best done with mist blowers which utilize air as the main carrier for the insecticide. These machines discharge only 1 - 2 percent as much spray volume as the conventional hydraulic machine while at the same time giving better coverage of the foliage.

Compressed air sprayers are small units operated by hand pump or fitted for carbon dioxide cylinders to provide the pressure. Compressed air sprayers have their greatest application in the nursery and plantation where occasional spot treatments are required.

Dipping is a useful means of treating nursery stock that has been dug and will be shipped as well as a variety of forest products. Insecticide materials are usually diluted when dipping nursery stock. Concentrated solutions may be used for treating wood products.

Soil fumigation is a useful treatment technique for soil born pests in nursery or plantation situations. Fumigation of a seed bed prior to planting may be done as a precaution to prevent damage from insect and disease pests.

# CHAPTER V

# MAJOR FOREST INSECT PESTS AND THEIR CONTROL

## Introduction

Insects attack forest plantings at every stage of growth and development. Plants of all age classes may be affected as well as all parts of a plant. Seeds, buds, flowers, foliage, boles and stems, roots and even products made from forest plants are susceptible to insect attack. It is beyond the scope of this manual to describe even a portion of the thousands of insects affecting forest growth. Insect pests that cause serious economic damage to forest trees and forest products, or that have an affect on forest management practices over a wide area are generally termed major. A survey conducted throughout the western states area asked foresters and entomologists to list those insects species they considered to be major pests in their respective region. While a few species were named as being pests in two or more of the regions, generally each region contained it's own compliment of major pests. The Rocky Mountain - Intermountain forest area contains the greatest number of major forest pests (19 listed in this survey).

Emphasis in this manual will be placed on the major pest groups affecting the intermountain pine and mixed conifer forest type. An effort will be made to include examples of each of the seven major insect orders listed previously that a forester in this region might encounter. For a more comprehensive discussion of western forest insects the reader is directed to the following texts:

Forest and Shade Tree Entomology by Roger F. Anderson. Wiley and Sons. 1960.

Principles of Forest Entomology Fourth Edition by Samual A. Graham and Fred B. Knight. McGraw-Hill. 1965.

Western Forest Insects by R. L. Furniss and V.M. Carolin. U.S. Department of Agriculture, Forest Service. Miscellaneous Publication No. 1339. 1977.

## Insects Feeding on or in the Foliage

This group includes the defoliators which, along with the bark boring species, compromise the two largest and most significant groups of forest insect pests. Insects in the defoliator group feed on and in the needles of conifers and the leaves of broadleafed trees, thus decreasing the trees ability to produce food. Some species are capable of causing complete defoliation of a tree in a very short time. Depending upon the tree species and time of year, such a radical reduction in leaf area could result in direct mortality of the tree. When defoliation is not as severe, tops, twigs, branches or cones may be killed. Limited defoliation may not cause tree mortality, however, tree growth, both in height and diameter are often retarded. Trees weakened by defolator attack are more susceptible to attack by other pests such as bark beetles.

Dectection Methods. Survey methods for defoliators in the past relied upon aerial and occasionally ground surveys which were often unable to detect population buildups until damage was nearing an economic status. Recently, detection methods have been developed that allow closer monitoring of certain defoliator populations. One method involves the establishment of plots within susceptible stands. Each season the lower branches of selected trees within the plots are shaken or beaten and the insects dislodged are caught on a cloth where they are counted and identified. This method allows for seasonal monitoring of populations and the implementation of control methods when necessary before significant damage can be done.

A second method involves monitoring populations with traps baited with a pheromone (sex attractant) specific to a particular species. Males are attracted to the traps and careful monitoring of the traps can provide information on population growth and trends. Trapping systems for the spruce budworm and the Douglas-fir tussock moth are now in use.

Control Methods. Control of defoliators has been the most widespread, successful and even controversial of the forest insect programs. Suppression measures involve the application of insecticides from the air. Many defoliators have been the target of aerial insecticide spray projects covering millions of acres over the past 30 years. The insecticides include conventional chemical compounds, viruses, bacteria, pheromones, juvenile hormones and feeding deterrents. Insect parasites can be effective in regulating certain populations. Introduction of foreign parasites have been made with limited success in the case of introduced defoliators such as the larch case bearer and others. Stand management practices may have some effect upon defoliator management, but much more research is needed. Leafminers like the cone and seed insects are much more difficult to control.

Defoliators and leafminers occur in four major insect orders: Lepidoptera, Coleoptera, Hymenoptera, and Diptera.

## LEPIDOPTERA

Adult insects in the order Lepidoptera have the following general characteristics: the presence of two pair of functional wings (Douglas-fir tussock moth female has only tiny rudimentary wings) which are covered with scales; the forewings are larger than the hind wings. The venation of the wings may be used to separate families and occasionally species. In most species the mouthparts are modified into a characteristic long, slender, flexible, sucking proboscis.

The larvae or caterpillars are generally characterized (with few exceptions) by possessing three pairs of jointed legs on the first three segments behind the head and from three to five pairs of short, fleshy, unjointed legs called prolegs on the abdominal segments. The mouthparts are of the chewing type. Refer back to Figure for a schematic drawing of Lepidoptera.

The order Lepidoptera is divided into two groups, the moths and butterflies. They may be easily separated in the adult stage by the following characteristics:

1. Moths: Antennae of various forms, but never with a knobbed tip. Most are night or twilight fliers. Wings usually folded along abdomen or spread horizontally when at rest. The pupa is often enclosed in a silken cocoon.

2. Butterflies: Antennae slender for most of its length, with the tip dilated to form a knob. Most are day fliers. Wings are held vertical when at rest. Pupa is exposed, never enclosed within a cocoon.

Butterflies and moths comprise the largest group of defoliators.

### Moths

The moths are the most widely distributed and destructive forest defoliators in western North America.

The WESTERN SPRUCE BUDWORM, [*Choristoneura occidentalis* (Freeman)] can be a pest of all the coniferous trees, with spruce, true firs and Douglas-fir being the more common hosts. The western spruce budworm, along with the mountain pine beetle (discussed below), represent the single two most widespread and destructive western forest pests.

The larval stage of the budworm destroys buds, cones, terminals, and foliage on all ages of trees. Feeding on the foliage is confined to the new growth, and rarely are the older needles damaged. This feeding habit continues through epidemic conditions. As a result of this feeding pattern, trees can lose much of their current season's foliage without suffering mortality. Severe new foliage loss that continues consecutively for three to four seasons will eventually cause tree top mortality. Crown mortality will continue downward until the entire tree is dead.

Spruce budworm epidemics have lasted only a few years, while others have persisted for as long as 52 years. The current spruce budworm epidemic in the Northern Region declined somewhat in 1979. However this was the first time in 17 years that visible budworm defoliation did not exceed 2,520,000 acres.

The adults are relatively small, mottled buff or gray moths. They emerge in late July and August. Eggs, which are light green, are laid overlapping like shingles on the underside of needles. The eggs hatch in late August or September and the young larvae overwinter in small cocoons under the bark scales on limbs and the trunk. In about May of the following year, the larvae leave the overwintering site, mine needles and developing buds. Later the maturing larvae feed on entire needles, webbing them loosely together. Pupation occurs in the webbing of needles. There is one generation per year.

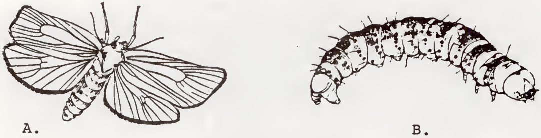


Figure 17. Spruce budworm.
A. Adult B. Larvae

Natural Control. Approximately 40 species of parasites, mostly wasps and flies, are known to attack the budworm. Predators include spiders, ants, beetles, and other insects. A number of birds are also predaceous on the budworm. Several disease pathogens have been isolated from budworm larvae, although disease has never been verified as causing the decline of an epidemic. Adverse climatic conditions can contribute to keeping budworm populations in check. Greatly reduced budworm populations levels have been attributed to late spring frosts.

Applied Control. Research is continuing into the effects of certain cultural factors such as thinning, harvesting methods, fertilizations, etc. There are several chemicals registered for spruce budworm control, i.e. Malathion, Sevin, Orthene, Dibrom. Experimental work is continuing with other insecticides including the bacterium Bacillus thurigiensis.

The DOUGLAS-FIR TUSSOCK MOTH, [Orgyia Pseudotsugata (McD)] is another widely distributed and destructive forest defoliator in the West. It defoliates primarily Douglas-fir and true firs. Other coniferous species are fed upon during times of high populations. Outbreaks of the Douglas-fir tussock moth appear to develop almost explosively and after about three years they usually subside because of virus infection, parasitism, weather and starvation. Some outbreaks, however, can persist for four years or more.

Defoliation like the budworms reduces tree growth, kills branches, tops, or complete trees, depending upon the intensity and duration of the infestation. Weakened trees are susceptible to other pests. In contrast to the budworms, larvae can feed upon and consume all ages of needles. Complete stripping of the foliage can occur within a few weeks under high populations. Tree kill in these stands can be 100 percent.

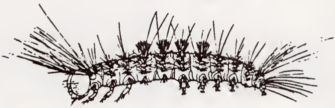


Figure 18. Typical tussock moth larvae.

The adult female, which has only tiny rudimentary wings, lays several hundred eggs in a mass in the fall. These eggs overwinter attached to the cocoons. The eggs hatch in the spring and many of the small hairy larvae are dispersed by the wind. Pupation occurs in late July and August. Adults emerge in the fall, with the winged males flying to the females for mating. There is one generation per year.

Because of the extent of the 1971-74 outbreaks and strong controversy over the use of DDT, widespread support developed for finding alternative ways of dealing with this insect pest. As a result, the U.S. Department of Agriculture, with the support of Congress, launched an expanded three-year research and development program in 1975 to help find new answers to the tussock moth problem. To date, encouraging progress has been made in development of a pest management system. The naturally occurring nucleopolyhedrosis virus has been registered, and several other compounds are being evaluated.

A chemical pheromone attractant trapping system has been developed to monitor seasonal fluctuations in tussock moth populations. In 1979 there were 28 trapping locations monitored in the Northern Region. Moth catches were extremely low indicating the pest was present but not approaching economically injurious levels.

Natural Control. There are many parasites and predators of the Douglas-fir tussock moth. A few species of flies cause high mortality in epidemic populations. The most important disease is a nucleopolyhedrosis virus which can wipe out an epidemic by its third year.

Applied Control. Research is continuing into non-chemical methods of controlling the Douglas-fir tussock moth. There are presently two compounds registered for tussock moth control - Dibrom and Orthene.

The LARCH CASEBEARER [Coleophora laricella (Hubner)] was introduced from Europe. In 1957, it was discovered attacking western larch in northern Idaho. Since then it has spread continuously through the larch stands of the Intermountain Region. In the Northern and Intermountain Regions, case bearer defoliation appears heaviest around lakes and along bottoms of drainages in northern Idaho and western Montana. In Montana heavy defoliation has occurred in the Flathead, Stillwater, Clearwater, and Fisher River drainages.

The insect gets its common name from the behavior of the larvae constructing a case from a mined needle. The insect produces one generation per year. The very small (wing expanse about 3/8 inch) silvery to grayish-brown adult moths emerge in late spring or early summer. Eggs are laid singly on the under surface of the needles. Upon hatching, the larva bores directly into the needle, feeding for about two months. After hollowing the needle, it constructs a case by lining the inside of the mined section with silk. This case is then chewed free from the rest of the needle.

Both ends of the case are open, the larva feeding from one end and pushing frass out of the other. The larva begins feeding externally upon the foliage about mid-August. It fastens its case firmly to a needle and then mines the interior as far as it can reach without actually leaving the case. After mining one needle the larva chews its case free and moves on to another. In the fall the larvae leave the foliage and attach their cases to twigs usually at the base of the needle fascicle. Overwintering occurs at this site. Larvae resume feeding in the spring at the time the new needles appear. The heaviest damage results chiefly from larval feeding on new foliage in the spring. Most of the needles can be stripped from the trees in the spring under heavy populations.

Because larch trees renew their foliage each year and can produce two crops of needles during a growing season, the trees are better able to recover from defoliation than are other conifers. They can withstand severe defoliation for four or more years before mortality is threatened. The greatest impact of case bearer defoliation of the tree is reduced growth, estimated to be as high as 90 percent in some years. When mortality occurs, it is believed to be combination of several factors.

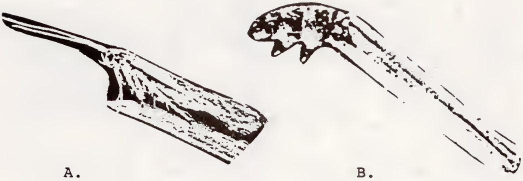


Figure 19. Larch casebearer.
A. Adult moth B. Larvae.

Natural Control. Three European hymenopterous parasites have been imported to control the infestation. Agathis pumila was imported in 1960 and has been distributed to more than 280 locations within the infestation. Dicladocerus westwoodii and Chrysocharis laricinellae were introduced in Idaho in 1972, and C. laricenellae was introduced in Montana in 1973. It is not known if D. westwoodii or C. laricinellae have become established. A. pumila is known to be established in 80 acres. There are 19 known native parasites of the larch case bearer of the

Western United States, but only two species are considered abundant.

Applied Control. Malathion ULV is registered for control of the larch case bearer, although forest managers have not used it as a control method to date. Zectran is being tested as an alternative to malathion.

The PANDORA MOTH [*Coloradia pandora*] can be a devasting defoliator of pines in western forests. Outbreaks have occurred in the past only in stands where soils are loose enough for larvae to burrow for pupation, such as the decomposed granite soils in the Rocky Mountain States. Epidemics occur in the West about every 20 to 30 years and may last 6-8 years. Even though feeding may be heavy during outbreak periods, it is often of little consequence since the terminal buds are not eaten. Also, the pandora moth has a 3 year life cycle so feeding is heavy only in alternate years, providing a chance for the trees to recover.

The adult is a stout bodied, grayish-brown moth with a small dark spot near the center of each wing. Males have large feathery antennae while the females are long and slender. Eggs are laid on the bark or needles of pine. The larvae are brownish to yellowish green with a shiny black head and several branched spines on each segment. The pandora moth completes a 2 year life cycle with adults appearing in July and eggs hatching in August. The young larvae overwinter in clusters at the base of the needles, resuming their feeding activity the next spring. They complete the larval stage by June, crawl down the tree and enter the soil where they form a small cell in which to pupate. The pupal stage usually lasts for 2 years but some may diapause for as many as 4 years.

Control. There are a number of natural factors which act to control outbreaks of the pandora moth. A polyhedrosis virus attacks mature larvae and once established is spread rapidly through the population leaving only a few larvae to survive. Ground squirrels and chipmunks dig up and destroy pupae. Birds, insect parasites and physical factors such as soil temperature also act to control the population. Chemical or silvicultural methods have not yet been devised for control of this pest.

TENT CATERPILLARS in the genus *Malacosoma* are commonly encountered in western forests. The western tent caterpillar (*M. californicum*) and the forest tent caterpillar (*M. disstria*) attack a variety of broadleaved trees and shrubs. Both species have similar life cycles. The adults are stout, yellowish to reddish-brown moths. They appear in mid-summer and prefer to fly at night, depositing their eggs in clusters either in bands encircling twigs or in a mass on limbs and boles. Young caterpillars are hairy and have blue, black and orange markings. The larvae are gregarious and tend to congregate within silken tents in tree crotches where they rest between feedings. By mid-summer, pupation occurs and adults emerge in about 2 weeks. There is only one generation per year.

Control. Natural control factors such as a variety of insect parasites and predators, birds and nucleopolyhedrosis virus effectively check tent caterpillar outbreaks. Although this pest is easily controlled by insecticides, it is seldom necessary to make application to forest plantings.

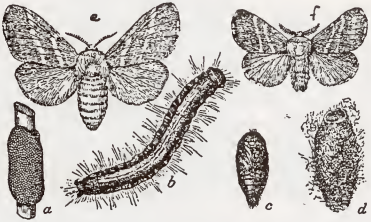


Figure 20. Life stages of a tent caterpillar.
a. Eggmass b. Caterpillar c. Pupae d. Cocoon
e. Female moth f. Male moth.

NEEDLEMINERS in the genus Coleotechnites can often reach outbreak population levels in western forests. The lodgepole pine needleminer (C. milleri) has reached epidemic proportions in the past, especially in extensive mature stands of lodgepole pine in California. Lodgepole pine needles in Montana are attacked by three related species , C. ardes, C. florae, and C. starki. A description of C. milleri will serve for these three species as well. During an outbreak, other pine species may also be attacked. The adults are small gray mottled moths with strongly fringed hindwings. The naked, blackheaded larvae vary in color from yellow to orange, pink, and red. Young hatching larvae mine individually into the pine needles near the tip and remain there through the winter. During the next season the larvae develop to the fourth instar mining in several needles in the process. They again overwinter in the needles and the next season continue developing through the fifth and sixth instars. Finally, pupation occurs within the needle with the adults emerging about a month later. This represents a 2 year cycle for this pest with the adults flying from mid-July to mid-August in odd numbered years.

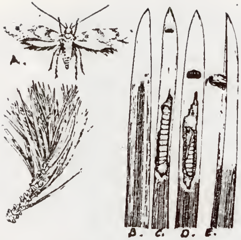


Figure 21. Lodgepole pine needleminer.
A. Adult B. First instar larval mine C. Mature larva
D. Pupae E. Adult emerging.

*Control*. Weather is an important natural limiting factor to the development of the pine needle miners. Low summer temperatures may kill adults and reduce mating. Wind, rain and snow storms may dislodge many needles containing eggs and pupae. The eggs and larvae are attacked by a multitude of parasites and predators. The larvae are susceptible to a granulosis virus. A number of bird species also collect larvae, pupae and adults. Applied control methods are being developed for this pest but as yet have seen little field use. Malathion is registered for insecticidal control, and effective if the application is timed to coincide with moth emergence.

*LEAFMINERS* in two genera, *Lithocolletis* and *Phyllocnistis* attack the leaves of poplar, aspen and other broadleaf trees and shrubs of western forests. The adults of these insects are tiny moths, their forewings elongate and yellowish with white cross bars and diagonal markings. Larvae may be cylindrical or flattened. The larvae mine between the leaf layers, some forming characteristic patterns. Nearly all species pupate within the mines. The *aspen blotchminer (L. tremuloidiella)*, the *aspen leafminer (P. populiella)*, and the *birch skeltonizer (Bucculatrix canadensisella)* are three species that may be encountered by the forester or range specialist.

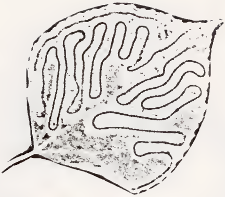


Figure 22. Typical leafmining pattern by aspen leafminer (Phyllocnistic populiell)

## Butterflies

A number of butterfly larvae attack broadleaf trees and shrubs in western forests and rangeland, however, very few can be considered important pests. The pine butterfly, Neophasia menapia, is however, one of the most destructive insect pests of ponderosa pine in northwestern states. Although the insect is distributed throughout the West, it has been more of a problem in Idaho. In one outbreak up to 90 percent of the ponderosa pines in a 150,000 acre area were killed, resulting in mortality of one billion board feet.

Ponderosa pine is the preferred host tree. Other conifers can be fed upon. Under ordinary conditions, larvae feed only on the older needles but under epidemic conditions they eat both new and old needles. Immature larvae feed gregariously on single needles at first, but later in their development will feed individually. Mature larvae migrate to bark crevices, limbs, or twigs, or they may lower themselves on silken threads to the ground vegetation where they transform to pupae. Mature larvae are approximately one inch long.

The adult butterfly is white with black wing markings and has a wing spread of about two inches. In general, it resembles the common cabbage butterfly. Eggs are laid in single rows on a needle.

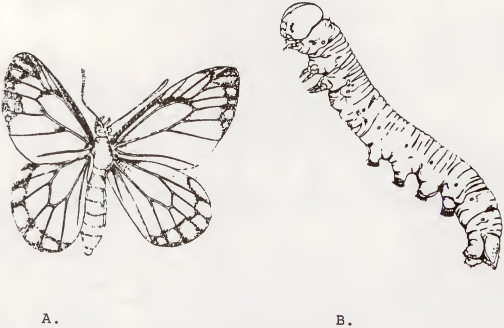


Figure 23. The pine butterfly.
A. Adult, female B. Caterpillar.

Natural Control. Past pine butterfly outbreaks have only persisted for about three years prior to collapsing due to pressures of natural enemies. Several species of insect parasites and predators have been associated with all past pine butterfly infestations. Birds are also known to feed heavily on pine butterfly larvae. Naturally occurring disease pathogens have been reported in butterfly populations but never at the level to give significant control.

Applied Control. Currently no insecticides are registered for pine butterfly control. Field testing of promising candidate insecticides is underway and may lead to the registration of one or more insecticides for pine butterfly control.

## HYMENOPTERA

Defoliators in the order Hymenoptera are commonly called sawflies. There are many species that feed on or in the foliage of conifers and broadleaf trees and shrubs.

The adults differ from other members of the order in that the abdomen is broadly joined to the thorax.

The name sawflies comes from the fact that the females have a saw-like ovipositor that is used to make slits in the needles in which an egg is deposited. A dozen or so slits may be made in a single needle. The adults appear to be more like flies.

Sawfly larvae can easily be separated from larvae of the moths and butterflies. The abdominal prolegs or falselegs of the sawflies start on the second segment, whereas the prolegs for the moths and butterflies start on the third abdominal segment.

The larvae feed gregariously in the early stages. Pupation occurs in cocoons on and in the duff or soil. The cocoons may be heavily preyed upon by rodents. Insect parasites also take their toll, but usually not until the pupal stage.

Various sawfly species are pest of pines, firs and larch. Birch, poplar, cherry, elm and willow are attacked as well. Although usually inconspicuous in numbers, some species periodically become prevalent enough to cause noticeable damage. So far, although extensive defoliation has occurred in some areas, the actual destruction of timber has been small and the outbreaks have quickly subsided.

Principal conifer feeding sawflies belong to the genera Diprion, Neodiprion and Pristiphora. By far the most important sawflies of concern to the western forester are the pine feeding sawflies of the genus Neodiprion. Species in this group may reach outbreak numbers locally or extensively. They feed on old foliage, some species preferring young trees while others attack mature trees. There are about 16 species of Neodiprion in the West and as a group they have similar life cycles and appearance. Females lay eggs in niches cut into the side of a needle. Upon hatching the larvae tend to feed in colonies until the later instars when they feed singly. Pupation generally occurs in the soil or forest litter but cocoons may be attached to the bark, foliage or other surfaces. Male and female adults are dissimilar in appearance, the male being smaller with feathered antennae.

Taxonomy of Neodiprion is somewhat confused. As a result species are sometimes hard to differeniate. At least one undetermined species attacks Douglas-fir. N. burkei attacks lodgepole pine in Montana and Wyoming. Other species attack ponderosa pine and true firs.

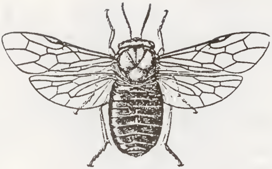


Figure 24. Lodgepole pine sawfly.

The larch sawfly (Pristiphora erichsonii) attacks western larch in Montana, Idaho, Washington and Oregon. While repeated defoliation has caused a growth reduction in larch, mortality does not occur extensively except in stands under other stress factors.

The adults of this species are 6-9 mm long and have a characteristic orange band around the abdomen. The larva has a black head, is pale beneath and gray green along the back. Males are not known. The adult female lays eggs in the young shoots causing them to curl. The young larvae feed first on the needles along the new shoots but soon move back along the branch to feed on older needle clusters. Mature larvae pupate in the duff where they overwinter. The life cycle is normally completed in one year but a few may remain in cocoons for 2 or 3 winters. Natural control factors are the principal limiting factors for this species. Silvicultural or chemical methods have not been developed that are applicable to a forest situation.

## COLEOPTERA

Beetle defoliators are generally not considered significant pests of western confers. Leaf beetles in the family Chrysomelidae feed on the leaves of broadleaf trees and shrubs. The alder flea beetle, (Altica ambiens), aspen leaf beetle (Chrysomela crotchi), and the cottonwood leaf beetle (C. scripta) are examples. The adults are small beetles varying in color from dark shiny blue to shades of brown and orange, some with markings on the wing covers. The grubs of these beetles as well as the adults cause feeding damage to leaves and shoots.

## DIPTERA

The larvae of small flies in the family Cecidomyiidae (gall flies) often cause economic damage to conifers and broadleaf trees by mining in the needles and leaves. The Douglas-fir midge (Contarinia pseudotsugae) mines the needles of the Douglas-fir causing a characteristic swelling of the needles. This species is sometimes economic in Christmas tree plantings. Adults emerge from the soil in early May and lay their eggs on the needles. The small yellowish larvae feed in the needles, often several per needle. At the completion of their larval cycle in the fall they drop to the ground and hibernate. Pupae form in the spring. Feeding causes premature dropping of the needles and some twig mortality can occur.

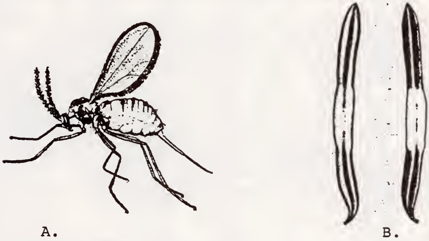


Figure 25. A. A typical leafmining midge adult. B. Mines in Douglas-fir needles by Douglas-fir needle midge.

## Insects Attacking the Inner-Bark

Insects in this category belong primarily to the orders Coleoptera (bark beetles) and Lepidoptera (pitch moths). A few other insects may be in this category but are considered to be of minor concern to the forester.

### COLEOPTERA

The order Coleoptera contains insects that are among the most destructive of all insects to forest and forest products. Most, but by no means all, of the injury is done by the larvae. These insects are characterized by having a complete metamorphosis and chewing mouth parts. The first pair of wings, the elytra, are hardened. The true wings, when present, are folded beneath the elytra.

### Bark Beetles

The bark beetles, super family Scolytidea, are one of the most destructive groups of insect pests to be found associated with coniferous forests. Besides killing living trees and breeding in the dying cambium of freshly felled trees and slash, some species bore pinholes through the sapwood of green logs and seriously reduce the value of the timber. Other members of the group are secondary in their attacks, and some breed only in dead and decaying wood.

The Scolytoidea differ from most other pest groups in that the adults mine beneath the bark and excavate egg galleries in fresh phloem. Consequently, they spend most of their active life out of sight.

The manner in which bark beetles select host trees has received considerable research over the past several years. It seems that pioneer beetles attack trees at random within a stand and when their attacks are successful they begin to attract other beetles to the same tree. Attraction consists of a pheromone released by the pioneer beetles in combination with volatile terpine emmissions from the wounded tree. These odors attract not only other beetles but also other insects which prey upon the beetles. Once the attack is fully underway, another pheromone is released that deters other beetles from the attacked tree.

Some species have no trouble starting an entrance on smooth bark, while others will spend considerable time seeking a roughed area, crevice, or junction of branch and trunk that presents a more suitable area to begin excavation. The entrance tunnel is gnawed by the parent adults through the bark, usually at a slight upward angle until the wood is reached. As the work progresses, fine reddish-brown boring dust and excrement are extruded through the entrance hole and collects in the bark crevices. In the case of those species which attack the cambium of pine trees, pitch and sap exude from the entrance hole and harden at the surface in various forms of pitch or resin tubes. Boring dust (frass) and pitch tubes are the first indicators that a tree is currently infested with beetles. The foliage of heavily attacked trees changes from green to yellow and finally to red as it dies, but this may not occur before the beetle brood has developed and left the tree.

Some adult bark beetles carry with them the spores of fungi which germinate and apparently aid the beetle in overcoming the tree. The egg tunnels are constructed from the entrance tunnel along the surface of the wood, cutting through the inner bark and often scoring the wood. With some species the tunnels are almost completely within the bark and may or may not be packed with boring dust and excrement. Eggs are laid along the sides of these tunnels. The eggs hatch into larvae or grubs that construct mines away from the egg tunnel at different angles depending upon the species. These mines are packed with excrement and boring dust.

With some species of bark beetles the mines are completely in the inner bark and are exposed when the bark is removed. Others mine for a short distance in the inner bark and then turn outward to complete their feeding and growth in the outer bark. Some feed entirely in the outer bark. The pattern of egg tunnels and larval mines of many species are separate and distinct from one another and is very useful in identifying the bark beetle species.

Pupation occurs at the end of the larval mine in a cell constructed by the larva. The cell may be in the outer bark or exposed in the inner bark. When the adult has become fully mature it gnaws a separate hole through the bark and emerges. In species that work en-masse, many individuals may use the same exit hole.

Adults may emerge at once and fly to attack new host trees, or may congregate in cavities under the bark before host trees and hibernate or wait until sexually mature before emerging. A few, upon emerging, feed upon twigs, buds, or bark of other trees before again breeding in the bark of a new host. Food tunnels made in this way are quite distinct in character from the regular egg tunnels.

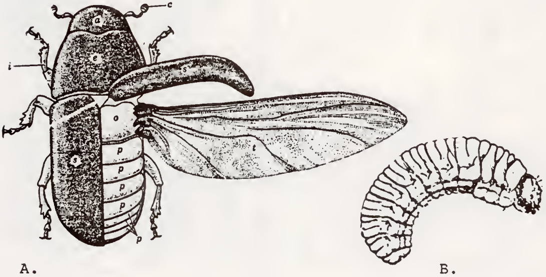


Figure 26. External anatomy of a bark beetle.
A. Adult a. head c. antenne e. pronotum i. leg
s. elytra t. membraneous second wing
p. abdominal segments. B. Larva.

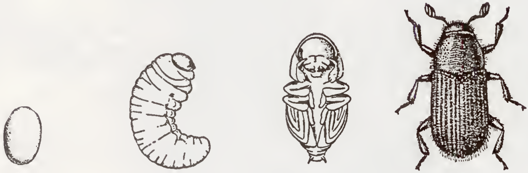
Adult bark beetles are small, cylindrical, dark-brown, reddish-brown, or black beetles, ranging in size from 1 mm in length to 10 mm. Most species are unicolored, either shining or dull.

The head is either exposed or more or less hidden by the pronotum. The mouthparts are of the chewing type with well-developed mandibles. The antennae are elbowed at the middle and clubbed at the tip. The abdomen is completely covered by the elytra and has five segments beneath.

The eggs are usually very small, clear or pearly white, and oval, round, or slightly elongated.

The larvae are always legless, cylindrical and curved, white, or cream-colored, with a distinct head and prominent mandibles which are dark-colored.

The pupae are white when first transformed but gradually take on a yellowish color as they approach the time for transformation to the adult. The antennae, mandibles, legs and wing pods are plainly visible on full-formed pupae.



A. B. C. D.

Figure 27. Developmental stages of bark beetle.
A. Egg B. Larva C. Pupa D. Adult.

Detection Methods. Trees killed by bark beetles are best detected by ground and aerial surveys with the latter being the most efficient for large areas. However, in normal years most bark beetles have left the tree before it turns reddish-brown. There are some exceptions; during dry years infested trees may turn yellow-green in the late fall and winter. Mountain pine beetle infested pines may fade while the beetle is still in the tree.

The best method of detecting trees currently infested with bark beetles is by ground surveys, examining each tree for the presence of boring dust or pitch tubes. Final confirmation can be determined by removing a piece of bark.

A rough estimate of population trend and damage can be made by comparing the numbers of previous years' faded tree crowns with current infested trees. Another method of determining population trend is to sample beetle populations under the bark. This method of sampling provides and opportunity to evaluate natural control factors that influence brood development.

Control Methods. Control methods for bark beetles can be classed as direct or indirect.

The objective of direct control is to kill or reduce the population of beetles in an area. Infested trees can be treated by one of several methods to destroy the brood. Often the attacked trees are sacrificed to protect their neighbors.

Direct control practices, still used occasionally in small areas, include fell-peel-burn, fell-deck-burn, fell-peel, fell-peel-spread bark, solar heat, and submerging the infested log. The trap-tree method developed in Europe has had varying degrees of success in the West. It should be apparent from descriptions of these methods that each method requires the felling of infested trees combined with some manner of beetle brood destruction.

The development of penetrating residual chemical insecticides has provided a means to protect high value unifested trees in recreation areas and around homes. Lindane and most recently, carbaryl have proved quite effective as preventative treatments. To date, no reliable method, either chemical or otherwise, has been developed to save a tree once it has become infested with bark beetles.

All of the above treatments are very costly and time consuming and therefore are not practical over large areas.

Another direct control method applicable to high value species in accessible stands in salvage logging of infested trees. Not only are beetle populations reduced by this method, but timber that would otherwise be lost is utilized, thus reducing the overall impact of the beetle infestations. As discussed in the previous chapter, salvage logging does have its drawbacks. It may not always be economically feasible to conduct salvage operations in small or remote areas.

Indirect Control. involves the incorporation of silvicultural practices into an overall forest management plant. Knowledge of host and site preferences for bark beetles allows forest managers to plan for and develop positive stand characteristics (tree spacing, species composition, age, class) that enhance stand vigor and growth while making the stand less susceptible to bark beetle infestation.

## Major Bark Beetle Species

Bark beetles vary in their ability to successfully attack forest trees. Those species that are able to attack and kill trees of normal vigor are considered primary. Species which are not able to successfully attack a healthy tree but normally attack dead or weakened trees are called secondary. Even the few primary species common in intermountain forest prefer to attack trees with reduced vigor. Historically, outbreaks tend to develop in stands affected by drought, fire or wind damage. Secondary species are often attracted to the same areas and attack trees already weakened by the primary species. A number of bark beetles attack twigs and branches without doing significant harm to the tree. These species are also termed secondary.

There are three principal genera of bark beetles the forester should be aware of; Dendroctonus, Ips, and Scolytus. Generally speaking, Dendroctonus species are primary, Ips secondary, and Scolytus largely secondary with the exception of two species, the fir engraver and the elm bark beetle. These three genera can be distinguished by their characteristic body shaped (see figure below).

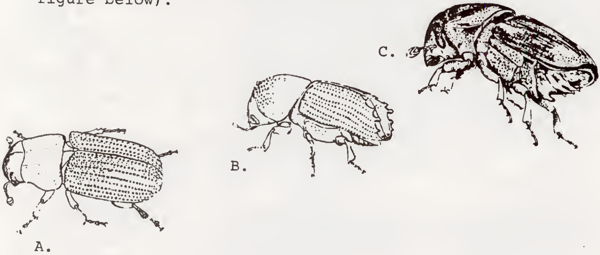


Figure 28. Side and top view of three bark beetle genera. A. Dendroctonus B. Ips C. Scolytus. Note the shape of the posterior in each genus.

The most significant primary bark beetle species in the est occur in the genus Dendroctonus (latin for tree killer). There are 12 species distributed in the West, four species of importance to the forester. All species breed under the bark of living or dying trees, or in fresh stumps or logs of various conifers. Some species attack living healthy trees while others attack only felled or weakened trees. Dendroctonus adults are 3-8 mm in length, cylindrical and dark reddish-brown to black in color. While the pattern of egg galleries vary from species to species, Dendroctonus adults work in pairs during gallery construction. Their egg galleries are always packed with boring dust and this characteristic distinguishes Dendroctonus beetles from other species of bark beetles. Table 4 serves to illustrate some of the characteristics of Dendroctonus beetle.

There have been four or five species of bark beetles that have caused the greatest mortality and concern in the Northern Region. The forester should be fully acquainted with these species.

The MOUNTAIN PINE BEETLE, [Dendroctonus ponderosae (Hopk)] is the major tree killing insect in lodgepole, ponderosa, western white, and sugar pine stands in the West. It also kills the high elevations species of limber and white bark pines. Outbreaks have occurred from the Black Hills of South Dakota to California. Tree loss can occur as scattered individual trees, but more often entire groups of trees are killed. Unchecked, these groups can expand with succeeding beetle generations and eventually large areas may suffer extreme losses.

Galleries of the mountain pine beetle are usually straight or only slightly winding near the bottom. Usually there is a short crook at the the bottom of the galleries 1-2 inches in length. The straight portion of the gallery may extend 12-36 inches and usually follows the grain of the wood. While the life cycle of the mountain pine beetle varies somewhat over it's range, one generation per year is the general rule. In colder climates it may take two years to complete the life cycle while two and a partial third generation may develop in warmer climates. The beetle overwinters in the larval and adult stage.

The mountain pine beetle caused extensive mortality on more than 2.5 million acres of lodgepole, white bark, ponderosa and western white pine in Montana during 1981.

The mountain pine beetle prefers standing green trees. Infested trees will thus fade while still infested, making the job of detecting these trees easier.

Natural Control. Natural control can be achieved by:

(1) abnormally cold autumn or winter temperatures,

(2) woodpeckers,

(3) predatory and parasitic insects such as

Table 4. Characteristics of Dendroctonus beetles

| COMMON NAME | SPECIFIC NAME | SIZE & COLOR OF ADULTS | EGG GALLERIES | LARVAL MINES | PUPAL CELLS | NUMBER OF GENERATIONS | COMMON HOST TREES |
|---|---|---|---|---|---|---|---|
| Western Pine beetle | brevicomis | 3 to 5 mm Dark brown to black | Winding between bark and wood | In phloem little exposed on inner surface | In outer bark | 1 and partial second to 2 and partial third | Ponderosa pine<br>Coulter pine<br>Lodgepole pine (rarely) |
| Southern Pine beetle | frontalis | 2.2 to 4 mm Brown to black | Winding between bark and wood | Practically all in phloem | Outer bark except thin-barked trees | 3 to 5 | Shortleaf pine<br>Loblolly pine & other pines & spruce in S.E. |
| Mountain Pine beetle | ponderosae | 3.7 to 6.4 mm Brown to black Head with frontal groove | Elongate Usually straight but sometimes sinuous | Grouped alternately on opposite sides of egg gallery. Exposed on inner surface | In phloem Usually exposed on removal of bark | 1 & a partial second in northern part of range | Lodgepone pine<br>Sugar pine<br>Western White pine<br>Ponderosa pine<br>White-barked pine<br>Limber pine<br>Engelman spruce<br>Mexican White pine<br>Pinyon |
| Douglas-fir beetle | pseudotsugae | 4 to 7 mm Red to dark brown Hairy | Vertical, sinuous, or straight Usually 12 to 14 in long. Occasionally 30 in. or very short | Fan-shaped groups. Mostly in phloem but may engrave wood. On alternate sides of egg gallery | In phloem Many or may not be exposed when bark is removed | 1 & a partial second | Douglas-fir<br>Western larch<br>Bigcone pine (usually secondary) |
| Northern spruce beetle | obesus | 4.5 to 7 mm Reddish brown to black | Vertical, straight, 6 to 8 in long | Grouped on opposite sides of egg gallery. First in phloem, later between bark and wood | Between bark wood. Engraving wood | 1 generation or 1 generation in two seasons | Mature<br>Black spruce<br>Red spruce<br>White spruce<br>Engelman spruce<br>Blue spruce |
| Red turpentine beetle | valens | 5.7 to 9.5 mm | Irregular winding or straight gallery at base of tree | Grouped along egg gallery and work in mass formation | Between bark and wood | 2 or more | All pines & occasionally spruce, larch & fir. (Primary on Monterey pine, other secondary) |
| Black turpentine beetle | terebrans | 5.0 to 8.0 mm | Elongate gallery parallel to grain | Eggs in groups along gallery and larvae feed in groups | Between bark and wood | 2 or more | All southern pines, most serious on loblolly slash longleaf |

* From - Principles of Forest Entomology by S.A. GrAhamand, F.B. Knight, 1965.

clerids ostomids, and small wasps, and

(4) diseases.

Applied Control. Control of the mountain pine beetle has been achieved by chemicals, felling and burning infested trees, and salvage logging. Lindane is one currently registered insecticide available to the pesticide applicator for mountain pine beetle control. A 20 percent emulsifiable concentrate is mixed with fuel oil or water per label directions. This is applied to the entire infested portion of the bole with a low pressure sprayer until the bark is throughly wet. Insecticidal treatment is effective only in the spring or early summer, prior to the adult flight. Sevimol (Carbaryl) 40% E.C. at the rate of 20 oz. per 100 gallons of water is also registered for mountain pine control.

Chemical methods are quite expensive and generally only practical for the treatment of high value pine in recreational areas or ornamental settings. In general, applied control measures have been only partially successful in controlling this beetle pest. Research is continuing in the use of pheromones and other attractants with a potential for altering the beetles behavior or protecting stands from beetle attack.

The DOUGLAS-FIR BEETLE, [Dendroctonus pseudotsugae (Hopk)] is one of the most important pests of Douglas-fir in the Northern Region. Western larch is also attacked but broods develop only in down timber.

The insect generally builds up to epidemic numbers in wind thrown, fire killed, ice damaged and other injured or weakened trees, then spreads in following years to more healthy trees.

Like adults of other Dendroctonus species, the adults of the Douglas-fir beetle work in pairs as they construct their perpendicular galleries in the inner bark of host trees. New adults emerging from the pupal cases bore through the bark and congregate just below the outside surface. They may remain there for long periods before finally emerging and flying off to attack new trees. There is one generation per year with the adults and large larvae overwintering. Overwintering adults generally emerge and attack new hosts from April to June. Adults from overwintering larvae develop and emerge in July and August.

Detection and Control. Like other tree species, Douglas-fir attacked by this beetle will turn yellowish and finally red. The red tops are an indication of a beetle infestation. Natural control of the Douglas-fir bark beetle is achieved by several species of predators and parasites as well as unfavorable weather conditions.

Direct control of the Douglas-fir bark beetle has not proved entirely successful. Prompt salvage of beetle killed, wind thrown or fire damaged trees aids in the reduction of Douglas-fir beetle populations in the coastal forests. While normal slash buildup has not been shown to be as important in beetle buildup in mountain forests, sanitation, thinning and harvesting to maintain a healthy vigorous stand does provide a high degree of preventative control in these forests.

The natural pheromones of the species, both aggregative and antiaggregative appear to hold promise of new control methods in the future.

The WESTERN PINE BEETLE, [Dendroctonus brevicomis (Le Conte)] is a pest primarily of ponderosa pine. It was probably the most serious pest in the early 1900's. With increasing forest management, the high risk trees were removed and the impact of this species reduced. However, it is still a problem, particularly after dry years.

The species is easily recognized by its work, which consists of winding, crisscrossing egg galleries between the bark and wood. Very little of the larval mines show on the inner surface of the bark. From one to three generations are produced each year, depending upon elevation and latitude.

Generally there are three flight and attack periods per season; spring, summer and fall. While two generations per year are common in the northern forests, there is considerable overlap of generations. Flight and attack usually begin in the late spring and continues until halted by cold weather in the fall. Commonly, the western pine beetle will attack a tree already under seige by other beetle species.

Natural control factors limiting western pine beetle populations include; cold winter temperatures (below -20 degrees F.), several insect predators and parasites, and woodpeckers. Direct control measures used with some success include felling and burning of infested trees, and general sanitation and salvage logging. The use of pheromones is also under study for this species.

The SPRUCE BEETLE [Dendroctonus rufipennis], occurs throughout the range of spruce in North America. Sporadic infestations of this species have caused widespread destruction of timber in the intermountain region. More commonly, the spruce beetle acts like other natural factors such as fire and wind as a means for thinning overmature stands. Spruce beetle outbreaks often develop in wind thrown timber and spread throughout the stand. All age classes except for young reproduction are attacked, with older, larger diameter trees preferred.

Spruce beetle galleries are vertical with the basal portion filled with frass. Two years are required to complete a life cycle in most spruce stands, slightly longer at higher elevations. In the Rocky Mountains, overwintering adults emerge in June and July. Larvae hatch, feed and overwinter, developing to adults by August of the following year. The new adults then emerge, fly to the base of a new host tree, bore in and overwinter. Insect predators and parasites, nematodes and woodpeckers are important natural control factors. Direct control methods include harvesting overmature spruce stands, sanitation and salvage operations.

The FIR ENGRAVER BEETLE [Scolytus ventralis] is a major enemy of true firs. Grand and white fir are its primary hosts in the Pacific Northwest. Although many other species of bark beetles cannot develop broods without first filling the tree, the fir engraver is able to attack and establish broods when only part of the cambium area of the trunk has been killed. Thus patches or strips along the bole can be killed, but the tree still survives. Severe branch and top killing can also occur and then even the entire tree can be killed during a single season. The trees that are weakened through successive attacks, die slowly over a period of years. Even though they survive the injury, partially attacked trees may develop defects and rots which render them unfit for manufacture into lumber and wood products.

The adults of the fir engraver are the largest of the Scolytus bark beetles. Egg galleries are constructed in the inner bark and cut transversal across the grain of the wood. Gallery excavation scores the wood, often deeply. Larval mines are constructed both up and down the bole, distinguishing the work of this species from that of related fir bark beetles.

While only one annual generation is produced, a second year may be required in colder areas. Direct control measures are generally impractical for control of this species because of the sporadic nature of infestations and the prevalence of brood in living trees. General stand sanitation is an important means of preventative control. Removal of infested trees in high value stands may be of some benefit.

The SMALLER EUROPEAN ELM BARK BEETLE [Scolytus multistriatus] is a potentially important bark beetle in Montana cities and towns. This beetle is a principal vector of Dutch elm disease, a fungal pathogen that has caused extensive reductions in elm plantings throughout the range of elm. Emerging adults seek out new host trees and tunnel in the crotches of limbs and twigs. Through their feeding activity they inoculate the tree with spores of the fungus carried on their bodies. Egg galleries are constructed with the grain of the wood and larval galleries fan off to the sides. There may be one to three generations a year with larvae, pupae and adults overwintering.

IPS - Beetles in the genus Ips are generally considered secondary pests. Ips beetles commonly attack trees infested by Dendroctonus species. or under stress from disease, drought, etc. There are some 25 Ips species recognized in the West, being primarily pests of spruce and pine.

As described in Figure 29, the pronounced concavity at the rear end of the adult is a distinguishing characteristic of this genus. There are a number of teeth (3 to 6) on each side of the cavity which, along with their size and shape, are useful in species determination. For identification purposes the species are numbered from top to bottom.

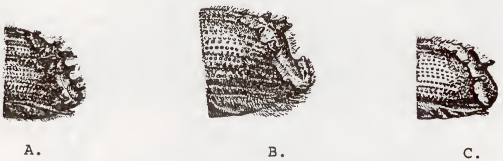


Figure 29. Enlarged posteriors of three common Ips beetles. A. Ponderosac B. Emarginatus C. Radiate.

Reddish or yellowish boring dust in bark crevices is usually the first sign of Ips beetle attack. Pitch tubes are not formed as with Dendroctonus species. Foliage of attacked trees turn from green to reddish. Unlike the egg galleries of Dendroctonus beetle which are often packed with frass, Ips galleries are free of dust for their entire length. Another Ips characteristic is the construction of a central nuptial chamber from which several egg galleries radiate outwards.

*Ips* attacks begin with the first warm spring weather. Attacks are initiated by a male who is later joined by several females after construction of the nuptial chamber is complete. Each female constructs an egg gallery, and deposits eggs along the sides. Hatching larvae feed in the inner bark and work away from egg galleries. A cell is finally formed by the larvae in which pupation occurs. About 1½-2 months is required from time of attack to adult emergence. There may be two to five generations of these species per season. Overwintering may include all life stages, however, adults are more common.

*Ips* beetles are attacked by a variety of predators and parasites, however, these natural control factors do not seem to exert as much population pressure as does the food supply. Freshly cut logs and slash are very attractive to *Ips* species. Thus, the piling and burning of slash before *Ips* emergence is a sound preventative practice. Prompt salvage of wind thrown and damaged trees will also minimize the buildup of *Ips* beetles.

*Ips emarginatus*, the *emarginate Ips* is commonly associated with the mountain pine beetle, however, on occasion it alone will kill trees. Egg galleries wind up and down the bole for 2-4 feet, resembling mountain pine beetle galleries. The *Ips* galleries have a nuptial chamber and are free of frass thus distinguishing them from mountain pine beetle. There are two generations per season in northern climates.

*Ips pini*, the *pine engraver* is a common transcontinental beetle which attacks all species of pine. Populations buildup rapidly in slash, wind thrown timber and in the tops of *Dendroctonus* damaged trees. When populations are dense they aggressively attack living trees. Frequently, small diameter trees are killed and during outbreaks, group tree killing similar to that of *D. ponderosae* occurs.

Generally, gallery patterns show 3-4 egg galleries forking from a central nuptial chamber, and remaining longitudinally with the grain of the wood, for 5-10 inches. From one to seven females with as many galleries may be associated with one male. There may be from 1-5 generations per year depending upon locality. Parent adults may emerge and make two or three successive attacks causing a confusing overlap of generations. Adults overwinter under the bark or in forest litter.

Preventative measures including slash disposal and salvage operations are superior to direct control methods.

## LEPIDOPTERA

### Pitch Moths

Pitch moths are also called clearwinged moths because of their narrow, more or less transparent wings. The adults are strikingly beautiful and wasplike, generally looking nothing like moths. They are day fliers and move very swiftly and hence are seldom seen.

Eggs are laid on the bark and in wounds of trees. Healthy and faster-growing trees seem to be preferred. Young stands are most susceptible to injury. Older trees having rough and thick bark are more immune, except where old wounds invite reinfestation.

The larvae are whitish and have a dark rounded head. Most of their activity is in the cambium region of the tree. Two years can be spent in the larval stage. The larvae are seldom directly responsible for the death of a tree. However, growth is reduced and the tree weakened with numerous attacks around the circumference of the tree. Damage consists of pitch seams, pitch pockets and checks in what would otherwise be absolutely clear lumber.

The ash borer, Podosesia syringae fraxini, and the Douglas-fir pitch moth, Vespamima novaroensis are examples of two pitch moth species common in northern forests.

The problem caused by these moths can be reduced only on high value trees. Control over extensive areas is not practical.

## Insect Attacking Wood and Wood Products

Losses of wood and wood products due to insects has been estimated at 1 to 5 percent of the annual harvest. Damage occurs when several insect species feed on or bore into wood. Damage may occur to logs after feeding but before utilization, to green or seasoned lumber, and even to finished wood products. Wood infesting insects often build up in fire killed, wind thrown, or insect weakened trees.

Insects in this group belong to the orders Coleoptera (ambrosia beetles, powder post beetles, round and flatheaded wood borers), Hymenoptera (horntails, carpenter ants), and Isoptera (termites). Generally, these insects are considered secondary forest pests since they seldom attack living trees. Detection, evaluation and control methods for wood infesting species are similar to those for bark beetles. Physical, mechanical and chemical methods are available to prevent or subdue infestation of wood borers and are, in many areas, more practical and economical than similar treatment for bark beetles. Prompt removal of timber from the forest, proper handling at the mill (debarking) and kiln drying help prevent attack by wood borers. Various chemical insecticides and wood preservatives also have application of prevention for attack by certain insects.

### Ambrosia Beetles

This group of beetles excavates their mines directly into the sapwood and heartwood of various tree species making so-called "pinholes". The frass or boring dust that these insects create is whitish and thus a means of separating their attack from bark beetles.

These insects are known as the ambrosia beetles because of their habit of propagating certain fungi called ambrosia which are eaten by both adults and larvae. Ambrosia beetles are distributed in five genera of two beetle families. This is one group of beetles that care for their young in much the same manner as do certain forms of social Hymenoptera (bees, ants, and wasps). The adult beetles carry in the fungus spores, prepare beds for them, and tend the gardens, which are fertilized by larval excrement. Each species has its own special variety of fungus. There must be a certain amount of moisture present in the wood or the fungus will not grow. Each colony will continue in a given host as long as conditions are right for the growth of their fungus food, but will abandon a tree as soon as it begins to dry out. Trees attacked by these beetles are dead or dying and the wood is in a fermenting condition before the attack is made.

Tunnel patterns vary between species. Since these beetles do not feed on the wood, the boring dust is cast out of the tunnels and collects on the outer bark. The pinhole borings and stains caused by the ambrosia fungi can seriously reduce the quality and value of the timber. There are several species of ambrosia beetles occurring in the West but these are usually not too important in the drier intermountain areas. Debarking, drying and proper storage of milled lumber are good preventative practices against ambrosia beetles.

## Powder Post Beetles

These beetles of the family Lyctidae are the most damaging insects of wood products. Although primarily pests of warm climate hardwoods, a few species do occur in the West. Adults are small, flattened dark brown to black beetles. Eggs are laid in open wood pores. Hatching larvae bore within the wood, turning it to a flourlike powder. There may be little external evidence of early attack, however as the larva nears maturity it cuts a hole into the wood surface and expels boring dust. Powder post beetles prefer to attack seasoned or seasoning wood with a moisture content between 6 and 20 percent. In the forest, there is typically one generation a year, with large larvae overwintering. However, under favorable storage conditions beetles develop continuously.

Painting, varnishing, staining, etc. will prevent powder post beetle attack. Heat treatment or chemical fumigation are effective in ridding infested wood of the pest.

## Flatheaded or Metallic Wood Borers

Beetles of this large group (family Buprestidae) attack a variety of forest tree species. Some attack apparently healthy trees while others concentrate on weakened or dying trees. Larvae bore first into the cambium then penetrate the wood. The large flattened tunnels are tightly packed with boring dust. While often very destructive to valuable trees, they are important in returning dead wood fiber to the soil.

The large whitish larvae are legless and flatheaded, hence the term flatheaded wood borer. Adults are often marked with striking metallic colors. Adults emerge in the spring, feeding for a short time on leaves or pollen before beginning egg laying. Eggs are laid in bark crevices or wood. Larvae feed throughout the summer and may overwinter as mature larvae, pupae or adults. One to several years may be required to complete a generation.

Control of those species mining the inner bark is similar to that for bark beetles. Chemical treatment or fumigation may be effective for killing larvae in infested lumber.

## Roundheaded or Longhorned Wood Borers

Western wood boring beetles in the family Cerambycidae are primarily cambium-wood feeders. Larvae begin by mining the cambium and then extending their tunnels into the sapwood and even the heartwood. Although they are damaging to wood products and logs, they seldom are important as tree killers. Like the flatheaded wood borers, these beetles are beneficial in that they aid in recycling wood back to the soil.

Adults are medium to large, oblong to cylindrical beetles with antennae often longer than the body, hence the name "longhorned" beetles. Female adults lay eggs in bark crevices and the hatching larvae extensively mine long, irregular tunnels packed with the coarse borings. Larvae are whitish, fleshy grubs, often plump but rounded at the head, resulting in the term "roundheaded" borer. Roundheaded wood borer larvae have a hardened, horny plate only on the top of the first segment behind the head. Flatheaded borer larvae have a similar plate on both top and bottom of this segment.

The life cycle and control of those borers are similar to those of the Buprestids.

Horntails

Adults of these pests are thick bodied wasps belonging to the order Hymenoptera, family Siricidae. There are 12 western species in four genera. All but one species attack conifers. Horntails are so named because of the short hornlike process at the end of the body. Horntails attack trees injured or weakened by other means. Adults are attracted to freshly felled timber and trees that have been scorched by fire. Females have been observed ovipositing in scorched logs that are too warm to keep one's hand on. These wasps seem to be attracted to smoke and can become so numerous as to be a nuisance to firefighters. The larvae mine and tunnel in the wood, greatly reducing its value. Horntails do not attack dry or seasoned wood.

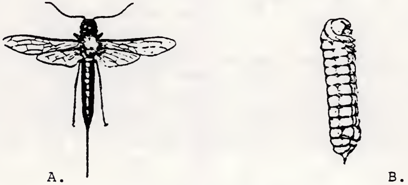

A. B.

Figure 30. Adult horntail wasp.
A. Adult B. Larva.

Adults are large and thickwaisted, the females with a stout, stinger-like ovipositor that extends straight back when not in use. Size and color vary greatly between species. Females lay eggs by inserting their ovipositor deeply into the wood. The larvae are cylindrical and yellowish-white bearing a small spine at the end of the body. Larvae mine entirely within the wood, packing the tunnels with fine dust. It takes 1 to 3 seasons to complete a life cycle. Several species are accompanied by symbiotic fungi on which the larvae reportedly feed.

## Carpenter Ants

The ants, like the horntail wasps, are in the order Hymenoptera but in the family Formicidae. They often construct their tunnels in stumps, fallen logs and portions of standing trees. For the most part, they are beneficial to the forester in helping to decay waste wood. Species in the genus *Camponotus* are most destructive when they infest structural timbers.

Carpenter ants bore in wood to provide living quarters but do not feed on it. They expel their borings or "sawdust" from their mines. In contrast, termites consume the wood in which they live and hence no "sawdust" marks their presence.

Preventive and corrective controls can be applied by pest control operators and home owners.

## Termites

These insects are in the order Isoptera. They are like the carpenter ants in that they are very destructive to wood and wood products. However, they are beneficial in the forest in helping to decay logs and stumps.

Termites, unlike carpenter ants, feed on wood celluose. In the forest they occur in felled trees, snags and stumps. Only a few termite species occur in northern forests.

Termites are social and live in colonies in the wood or soil. There are several forms of "castes" within a colony (worker, soldier, reproductives, etc.). There are winged and unwinged forms. Termites are often called white ants, but can be differentiated from ants by the lack of constriction between the thorax and abdomen.

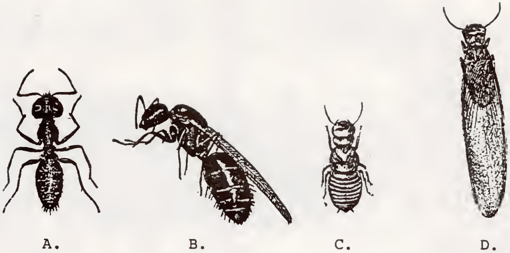


Figure 31. Comparison of ants and termites.
A. Carpenter ant worker and B. Queen
C. Termite winged adult and D. Worker.

Termites may be broadly classed as dampwood termites (feeding in damp decaying wood), drywood termites and subterranean termites. The western subterranean termite, Reticulitermes hesperus occurs in the Northern Region. Termites are seldom economic pests in western forests but can become quite damaging to wooden structures.

## Sucking Insects Attacking Buds, Seeds and Foliage

All the insects discussed in the preceding section feed upon the tissues of trees by ingesting the solid parts. All of them have madibulate or chewing mouthparts. Another large and important group of insects live upon the sap of plants. Their mouthparts are of the sucking type in which the parts have become slender, bristle-like organs enclosed in a sheath. The mouthparts form a beak used to pierce the tissues and extract the fluid.

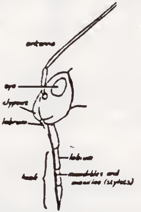


Figure 32. Sucking type mouthparts typical of Hemiptera and Homoptera.

The effect of sucking insects upon trees is much less conspicuous than is the effect of defoliators and bark beetles. Only a few species seem able to kill trees directly.

Sucking insects may injure forest trees in the northwest in two ways: 1) directly by sucking the sap, thus robbing the plant of a part of its supply of food and water; and 2) indirectly by producing necrotic spots or swellings.

The sucking insects attacking trees belong to two orders: the Hemiptera and Homoptera. Mites, related to insects, are also important sucking pests.

## HEMIPTERA

Only a few species in this order are considered forest pests. Others are beneficial predators of defoliators and other forest pests.

The western conifer seed bug, Leptoglossus occidentalis is in the family Coreidae. Bugs in this group are often referred to as leaf footed bugs because of the flat tibia of the hind legs.

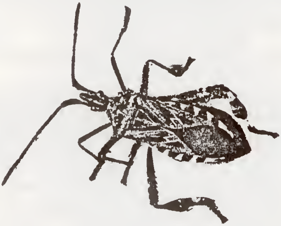


Figure 33. Typical seed bug.

The western conifer seed bug feeds upon the seed of Douglas-fir, pines and incense cedar. Adults are small, reddish-brown to gray bugs. Females lay their eggs in rows on needles. Overwintering is in the adult stage, with one generation annually.

The boxelder bug, Leptocoris trivittatus is a common Hemipteran throughout the West. It prefers to feed on seed bearing boxelder trees, attacking the seeds. There are two generations annually, with the adults overwintering. While seldom a pest of consequence in the forest, it often becomes a nuisance to homeowners in the fall when adults enter houses to overwinter.

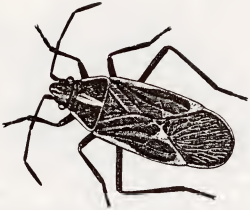


Figure 34. Boxelder bug.

## HOMOPTERA

Various forms in this order make up the major forest sucking insects.

### Aphids

Among the Homopterous sucking insects the family Aphididae stands out prominently as an injurious group. They are abundant, both in numbers of individuals and species. Aphids are so generally distributed that it is scarcely possible to find a tree of sapling size or larger which is not infested by them to some degree.

Aphids are usually very small, soft-bodied insects with pear-shaped bodies. The legs are long and slender. Aphids may be black or greenish, either winged or wingless. When wings are present, all four of them are transparent, delicate and with a few simple or branched veins.

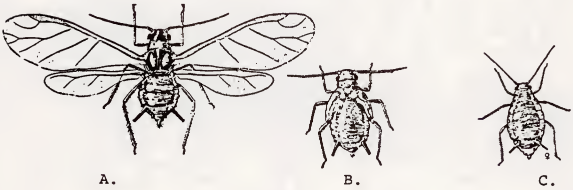


Figure 35. Aphids.
A. Winged female B. Winged nymph C. Wingless female.

Different aphid species have different habits. Some of them live on the bark of the trunk, branches and twigs. Others confine their feeding to the needles or roots. Some aphids provide shelter for themselves by forming galls, or by secreting a flocculent, wax-like material which collects over them and affords protection from their enemies, weather and certain insecticides. Still others live unprotected on the foliage of the trees.

Most aphids excrete a sweet material called honeydew, which is highly prized as food by ants and other insects. It is a common sight to see ants busily collecting this sweet liquid. In some instances the ants care for the aphids and in return receive honeydew. It is because of this relationship that aphids are sometimes called ant cows. A sooty mold fungi may develop on the honeydew excreted by the aphids and some scale insects. The black material consists of fungal hyphae. The hyphae do not pentrate the living needle tissue. Although sooty needles are unsightly and some interference with their physiological functions must result, there is no apparent injury to affected trees. Preventing honeydew formation by controlling the aphids is the best way of dealing with the sooty mold problem. At certain times, the honeydew itself can be a nuisance when it drips down onto picnic tables, etc.

When aphids occur in small numbers, the direct injury caused is comparatively slight. However, when they become very abundant as they frequently do under favorable weather conditions, their injury to the trees is often great. Only a few species may kill trees. Most of the injury that they cause results in a reduced rate of growth and in a generally unthrifty condition. Trees injured by aphids may succumb to secondary insects or fungous diseases.

Aphid populations fluctuate greatly owing to the effects of weather, parasites, predators and disease. Aphids normally reach economic population levels only in nurseries or plantation plantings. Early detection and chemical treatment of building aphid populations is the key to preventing damage.

The most common aphids found on forest trees in Montana are those in genera _Pineus_ and _Cinara_. The host range of these aphids is wide and they are commonly found on Douglas-fir, pine, spruce and the true firs. Damage is primarily confined to the twigs, buds, needles, branches and roots. Distortion of terminal leaders and of young twigs can result from aphid infestations.

Another group of aphids important in forest trees are in the family Adelgidae and genus _Adelges_. Members in this group live on the needles, twigs or in galls on conifers. Some species alternate between two different conifer species and cause different types of damage on separate hosts. Species in this family differ from the other aphids in that they all produce a waxy or woolly material. They are definitely more injurious than the true aphids.

The COOLEY SPRUCE GALL APHID [Adelges cooleyi] is common on Douglas-fir and spruces. It is not considered important on forest trees being grown for timber. However, it can be a serious pest of Christmas trees and ornamentals.

The aphid is responsible for the formation of cone-shaped galls on the twigs of blue, Engelmann and Sitka spruce. THe galls can be from one to two inches long, light green to dark purple and are formed by the growing together of the basal portion of the needles so as to form chambers between the base of the needles and the stem. The galls turn brown, dry and harden on the trees after the insects have escapes and they may persist for many years.

On Douglas-fir the aphid attacks the undersides of the needles. Small cottony tufts are formed over their bodies. Juices of the needles are sucked out causing the needles to turn yellow in spots. Sometimes the damage is so severe the needles turn brown and premature shedding occurs.

The seasonal history is very complicated and will not be discussed in this writing. THe aphis cycles between spruce and Douglas-fir, but apparently can complete its cycle only on one host if the alternate is absent. infestations are usually more severe when both hosts are present.

Acceptable controls can be achieved on individual trees by the use of conventional insecticides.

## Scales

The scale insects are in the family Coccidae. The insect body is covered with a relatively hard scale that may be either round or elongate, white or black.

The two species, the Pine Needle Scale, (Phencaspis pinifolae), and the Black Pine-Leaf Scale, (Nuculaspis californica), attacks the needles of pines and occasionally other conifers and are the most common scales on forest trees. Infestations are often associated with conditions where dust and smoke are found in the atmosphere. The choking of stomata in the needles by foreign particles probably renders them susceptible to these insects.

Damage from these species is most severe in Christmas tree plantations and ornamentals. Control can be achieved by the timely use of conventional insecticides.

### Spittlebugs

These insects in the family Cercopidae are called spittlebugs because of the mass of white froth, resembling spittle, which covers odd-looking, hopperlike insects. The insects are well-protected by this frothy secretion. The adults are known as froghoppers.

Spittlebugs are more common on pines, but do occur on other species. Heavy infestiations can seriously affect young trees. Chemical controls for individual trees are available.

### Mites

Most of the mites considered to be important on forest or ornamental trees are called spider mites in the genera *Tetranychus* and *Paratetranychus*. They suck the juices from needles causing spotting, fading, yellowing, or heavy needle fall. Heavy infestations made the trees appear as if they were scorched. Heavy silvery webs are often associated with the damage.

Populations of mites often increase after periods of long, dry, how weather and in areas receiving repeated insecticide treatments.

Direct control can be achieved by "washing" individual trees with high water pressure, applying dormant sprays, some insecticides or miticides.

## Insect Pests Important in Forest Nurseries and Plantations

### Nursery Pests

Insect enemies, damping off, rodents, heat injury and less than ideal soil conditions are a few of the factors a forest nurseryman must contend with. Whether seedlings are grown in containers, greenhouse bench flats or nursery beds, they may be susceptible to number of insect pests capable of damaging roots, stems and leaves. Nurseries like an agricultural planting offer a monoculture environment conducive to rapid and extensive insect pest buildup.

The major groups of insects attacking seedlings in western nurseries are weevils, white grubs, cutworms, wireworms, aphids, scales, sod webworms, various beetles, earwigs, grasshoppers, thrips as well as mites. Root feeding insects are generally most troublesome in newly broken ground previously covered with sod. Insect problems can vary tremendously in a nursery from year to year.

While insect pests in western nurseries are seldom a widespread problem, there are several preventative measures in common use. Soil fumigation is now becoming a common practice and will control nearly all stages of soil inhabiting insects as well as many disease organisms. Methyl bromide is injected into planting beds. Plastic tarping is then spread over the bed and secured tightly to the ground to prevent gas escape. The tarp is left in position for a number of hours specified on the label and then removed prior to planting. Liquid and granular insecticides are of use in some situations. Mechanical methods such as plowing and tilling are also useful in preventing the buildup of weeds and some insect pests. Nursery pests are often easily monitored with various attractant traps, light traps and pheromone traps.

## Plantation Pests

The increasing interest in nursery and plantation plantings has led to greater attention being focused on a group of insect pests not previously considered significant. Basically, these plantings are subject to the same group of insect pests attacking natural regeneration in the forest. However, the monoculture environment created by a plantation hastens the buildup and spread of these pests.

Root and stem infesting insects are the same groups that attack nursery seedlings and mature forest trees and will not be discussed further here. Insects attacking twigs, terminals and buds impact young trees by 1) extensive killing of lateral branches and terminal leaders; 2) deformation of the trees resulting in forked or multiple tops; 3) reduction of tree growth thus prolonging the time required for trees to reach merchantable size; (4) occasional killing of young trees. Several of the more important twig, terminal and bud infesting insects are discussed below.

## Pine Shoot Moths

There are several species of pine shoot moths inhabiting western forests. They can be especially troublesome in plantations where they cause damage by mining the buds and shoots of young pines. Infested trees are often deformed and their growth rate is retarded but mortality seldom occurs directly as a result of pine shoot moth attack. Trees varying in height from seedlings to 25 feet are the most susceptible.

The Western pine tip moth (Rhyacionia bushnelli) occurs in Montana, the Dakotas and Nebraska in young pine stands. Various other pine species are also attacked by the larvae of this mottled grayish and brown moth. The larvae are yellowish with black heads. Moths lay their eggs in late May on the pine needles, buds and shoots. Larvae of the single generation feed through July. The winter is passed as a pupae in the soil litter.

Another very important pest in this group is the European pine shoot moth (Rhyacionia buoliana). Although not known to occur in Montana, it is a pest of pine in neighboring states to the east and west so the Montana forester should be alert for the first signs of introduction of this pest.

The European pine shoot moth was first detected in 1914 infesting Scotch pine in New York state. Subsequent surveys indicated the insect was present in at least ten states. A federal quarantine was placed on the importation of pines from Europe. Early attempts at eradication failed and the moth spread to forest plantations, city plantings and nurseries. Presently, the moth is generally distributed along the eastern seaboard, in the Central States, Lake States and eastern Canada.

Detection of the European pine shoot moth in the West was first made in 1927 in mugho and Japanese red pine in a nursery in Victoria, British Columbia. The infested pines were destroyed and the moth was not reported again until 1938. In recent years the shoot moth has been recorded in both Victoria and Vancouver, B.C. In 1959, European pine shoot moth infested red pine were found at Bellevue, Washington. Surveys conducted in 1960-1961 indicated the moth was generally distributed in the Puget Sound area of Washington and around Portland, Oregon and Spokane, Washington.

Surveys and eradication efforts continued throughout Oregon and Washington. By 1967, the moth was reportedly attacking mature trees over larger areas and eradication by host destruction was abandoned. Fumigation and the application of contact insecticides became the operational approach whenever the insect was found. Survey efforts for the pest continue and control measures applied when applicable. Several years of pheromone trapping in commercial pine plantations of Montana by the Montana Department of Agriculture have failed to detect the presence of the European pine shoot moth.

This insect is primarily a pest of young pine trees. Red, mugho and Scotch pines are attacked most severely. Other favored hosts are Austrian, jack and Japanese red pines. Ponderosa pine and lodgepole pine are also attacked in this country. The adults are small, buff-colored moths with a wing expanse of 3/4 inch. The forewings are orange to brownish-red, marked with six irregular silvery cross lines and the hindwings are dark brown. The larvae grow to 5/8 to 3/4 inches long and are reddish-brown in color with black heads and collars. The pupae are about 3/8 inch long, robust, dark yellow brown, with rows of small dark spines on the abdomen. Eggs are only 1/32 of a inch long, flattened, oval in shape and change from light yellow to a light brown during development.

There is one generation a year in America. Adults appear late in spring and fly during the night. Eggs are laid singly or in groups of two to ten on the tips of the twigs, on the stem, needle fascicles, or at the base of buds. The upper part of the tree is preferred for oviposition. Hatching larvae bore into the fascicle sheaths after building a protective silken tube. About midsummer the larvae bore into buds where they remain for the rest of the summer and through the winter. In spring, larvae leave the buds in which they overwintered and attack uninfested buds or expanding shoots. Buds are normally killed while shoots are usually malformed, subsequently causing a crook known as a posthorn. Upon completing feeding, larvae pupate in tunnels in the buds or new growth. After two to three weeks, the pupae wiggle out of the tunnel until mainly exposed and the adults emerge.

The presence of larvae is indicated by small whitish masses of resin on the buds, accompanied by dead needles resulting from the early mining of the needle bases. Previous injury is shown by bushy growth on the leader and ends of the branches, forking of the leader, stunting of the trees and distortion of the leader into a "posthorn" or "bayonet tip". Sometimes a severe infestation may result in conspicuous defoliation of the upper part of the trees. Under heavy infestation complete stagnation of tree growth takes place.

European pine shoot moth infestations can be most readily detected in late summer when the discoloration of the needles on the infested shoots is most conspicuous. Detection is also practicable in winter and spring by close examination of bud clusters for typical pitch deposits caused by larvae mining in buds. Detection of light infestations is difficult and is complicated by the fact that damage by other insects, such as the pitch nodule moth, the Zimmerman pine moth and related species of Rhyacionia, may be confused with that of the shoot moth.

Recently, the pheromone of the European pine shoot moth has been identified and the material has been used in sticky traps for detection. This method has proven to be more effective and less expensive than the visual ground examination.

Native insect parasites cause only small reductions in shoot moth populations. Three parasites introduced from Europe into the eastern states have been more effective, but cannot reduce damage perceptibly unless the spread of the shoot moth is retarded by care in planting susceptible pines. At present six species of parasites are being introduced into the central states and lake states on an experimental basis. While epidemics do occur in Europe, they are effectively controlled by the natural control factors in combination with careful cultural practices.

Cold winters can be effective in reducing shoot moth populations. Removal of infested shoots in spring is an effective means of providing partial control of the shoot moth on ornamentals. Use of this method in plantations is not usually practical because of the cost and not effective unless all infested trees in the plantation and the immediate vicinity are treated. Even then, a substantial shoot moth population remains, due to the difficulties in finding some of the infested shoots.

Chemical control by ground spraying has been successful in controlling the insect. A number of insecticides (both systemic and contact) have been tested and are being used. Timing of the spraying can be directed at the egg, larval, or adult stages. Several applications, about 10 to 14 days apart, are necessary. Drenching of the trees is necessary in order to get the insecticide deposited at the base of the needles and on the buds. Spraying to date has only been done in nurseries and ornamental plantings. At present spraying may be too expensive to be practical in forest plantations. Helicopter and airplane spraying have been attempted on an experimental basis and the results have not been satisfactory.

Prevention of spread of the shoot moth from nurseries is an important step in control. Annual inspection of young pines during late summer or fall will disclose whether or not the insect is present. If so, chemical control should be applied as a routine measure. Fumigation of dormant planting stock with methyl bromide prior to shipment is important if a nursery is known to be even lightly infested.

Treatment of baled seedlings in a fumigation chamber and tent fumigation of small ornamental trees is effective at a reasonable cost. Control may not be 100% and is dependent upon gas concentration, length of time and temperature. Serious injury can occur to the treated trees if conditions are not ideal. Fumigation by experienced, licensed applicators is highly recommended.

## Western Pine Shoot Borer

The western pine shoot borer (Eucosma sonomana) reached significant pest status in the 1960's when it was found to damage terminal leaders of pines. The adults are small, light brown moths with a wing expanse of about 1/2 inch. Fully grown larvae are creamy white and about 5/8 inch in length. Adults emerge in the spring. Mating and egg laying take place when temperatures are between 30 and 40 degrees F. Eggs are laid by the night flying moths at the start of bud elongation on ponderosa pine. Larvae bore directly into the pitch of expanding buds, both lateral and terminal. On ponderosa pine, the shoot apex appears to be a preferred entry site. The larvae exit through the side of the shoots, leaving a circular hole about 1/8 inch in diameter. Dropping to the ground, the larvae enter in the soil overwintering as pupae.

While ponderosa pine is preferred, lodgepole, Jeffery pine and Englemann spruce have also been reported as hosts.

Symptoms of infestation become readily apparent in summer once pine shoot elongation and needle growth are completed. Stunted shoot length, indicated by a disproportionally increased density of needle fascicles, and substantially shorter needles in the distal shoot portion are the most apparent symptoms. The "shaving brush" appearance of ponderosa and Jeffery pine terminals is a reliable and easily observable infestation characteristic when compared to the uniform needle length of an uninfested terminal. Injury symptoms on other western pines are similar, although they are harder to distinguish on lodgepole pine.

The western pine shoot borer does not leave feeding scars, webbing or frass on the surface of infested shoots. Larval mining inside elongating shoots impairs or stops shoot and needle elongation. The injury frequently affects the formation and subsequent development of new buds. Reduced tree height and deformed crown result from repeated borer attack.

## Pine Needle-Sheath Miner

The pine needle-sheath miner (Zelleria haimbachi) is a native moth distributed over much of North America. It is not a rare species, but individuals are small and they and their work are relatively inconspicuous unless the population is large. The pine needle-sheath miner attacks and defoliates several of the two-and-
three needle pines. Ponderosa, Jeffery and lodgepole pines are the principal hosts in the West.

The adult moth is white bodied with a 12 mm wing expanse. The forewings are golden-yellow, each with a broad white median longitudinal band; the hindwings are white.

The eggs are oblong, whitish, somewhat transparent and are slightly flattened on top. They measure about 0.3 mm by 0.6 mm.

Newly hatched larvae are thread-like in appearance, about 1.5 mm long and only 0.10 mm wide. The head capsule is shiny black and the remainder of the larvae is bright orange and somewhat mottled. The larvae are essentially without hairs. In later instars, the orange color fades to tan, with two dull orange stripes running lengthwise along the center line of the body. The head capsules of the later instar larvae are tan. Shortly before pupation, the larvae take on a green color. At this point they are about 14 mm long. There are five larval instars.

The pupae are about 7 mm long. When newly formed, they are bright green, but they turn brown within 48 hours.

Eggs are laid singly on the current year's needles in midsummer, and the first instar larvae overwinter as needle miners in the needle on which the egg was laid. In the spring, larvae start to feed on the tender tissue within the sheaths of newly developing needle fascicles. The needles are severed within the sheath and a considerable amount of webbing is produced around the bases of the needles. Each larva requires about ten fascicles for development and under high population densities nearly every needle on a tip may be destroyed. Pupation takes place in early summer in the tips where larvae have been feeding and lasts about two weeks.

During the late summer and fall, when the larvae are true needle miners, they are particularly difficult to detect. The only evidence is a thread-like mine along the needle edge. Barely visible to the naked eye.

When populations are heavy, needle-sheath miner infestations are easily detected. The first sign is usually a fading of some of the developing needles of the new growth. Small to large amounts of fine silken webbing can be seen around the needle bases. The larvae are found within this webbing in the spring.

Needles are attacked throughout their period of elongation. The shorter ones merely cease growing and begin to fade, but the longer ones are cut off within the needle sheath and tend to droop back sharply at the sheath. Eventually those needles that are fed on are blown away by the wind. The resultant thinned-out tip remains through the rest of the year and is evidence of the needle-sheath miner's activity.

There are a number of parasites that are believed to play an important role in keeping populations in check. Both ground and aerial application of conventional insecticides can be effective in controlling this insect.

### Gouty Pitch Midge

The gouty pitch midge (Cecidomyia miniinopsis) belongs to the larger family of flies, called gall midges. This species is noted for its damage to twigs. Although not a true gall producer, it causes swellings and other malformities in twig growth.

The adult midge is a small delicate fly, resembling a mosquito. The body color in both sexes is dark to brown, except for the abdomen which is crimson. The wings are transparent. The egg is nimute, being 0.4 mm long by 0.1 mm wide. Its color is crimson to pink. The larva is a typical fly maggot, somewhat flattened and tapers at both ends. When full grown it is 4 mm - 5 mm long and its color ranges from birght orange to red. The pupa is encased in white cocoon, much like a moth cocoon. It is usually attached to a needle.

In the West, the chief host is ponderosa pine. The gouty pitch midge will attack Jeffrey pine when this tree species it grows near infested ponderosa pine. Damage similar to the gouty pitch midge had been reported on lodgepole pine.

Pitch midge adults are active during the spring months. Eggs are laid on expanding branch and leader tips of the host trees during the period of rapid spring shoot growth. They are not forced into the tissue, but are simply placed on the surface.

The young larvae mine into the bark to form a tiny pocket or feeding pit, about 4 mm long and 3 mm wide.

the larva becomes immersed in resin fluid. Larvae feed until the following spring. As they mature they work themselves to the surface of the shoot and leave their feeding pits to pupate in cocoons. There is one generation per year.

Dead needles, dead or dying twigs and distorted, twisted termainal growth are the general indicators of gouty pitch midge activity. The needles die in tufts and as they die they droop, turn yellow and later reddish-brown. These "flags" due to the midge begin to appear in the summer, but are most conspicuous in late winter or early spring of the year following attack. Later they break off and fall to the ground. This "flagging" results when the pits formed by the maggots are numerous enough to girdle the shoot.

Midge infestations are seldom uniformly distributed throughout the stand. Trees, in some spots, may be heavily infested, while others a short distance away are not. Prolonged, severe infestations usually deform or stunt the crowns. Ordinarily, few trees die from midge attacks, but extensive killing of lateral branches and terminal leaders over a period of years reduces tree growth sharply. It also prolongs the time required for trees to reach merchantable size. The younger age classes of sapling and poles 4 to 16 feet in height are most heavily infested. Older individuals are sometimes attacked, but usually only in the lower parts of the crown.

The midge is host to several parasitic insects that help keep populations in check.

## Spruce Weevil

The spruce weevil (Pissodes strobi), also called the white pine weevil, kills the terminals of young Sitka spruce, Engelmann spruce, and pines in the West. In some stands 30 to 40 percent of the trees are attacked year after year. As a result, planting of Sitka spruce has been greatly reduced the last few years. Sitka spruce is capable of competing well with brush and is quite resistant to animal browsing.

The weevil adults are 4.5 mm to 6 mm long with long curved beaks typical of weevils. The body is reddish-brown with patches of lighter brown or gray and is covered with scales. The eggs are pearly white, nearly round, and about one-half the size of a pin head. Larvae are white, legless grubs with light brown heads and about 5 mm long when mature. Pupae are completely white except for the eyes.

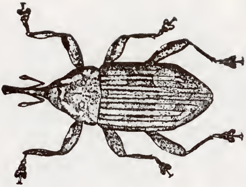


Figure 36. White pine weevel.

The adults overwinter in the foliage of the tree, usually at the two and three year old branch nodes. They feed on the phloem of branches throughout the winter. Adults are very difficult to find and dislodge from the foliage. They climb to the top of brood trees about mid-April, mate, and fly to new hosts where they feed and lay eggs on new leaders. Egg deposition starts in late March and last until June. The eggs are deposited in the terminal near the top and usually on the north and northeast sides. Larvae hatching from eggs mine down the terminal, gradually reducing the area of phloem tissue. They mine under the bark of the one-year old terminals and sometimes into the two-year old terminal. About mid-July the phloem tissue to the developing terminal is completely severed and the terminal begins to turn brown and droops.

The larvae begin to construct their pupal chambers about mid-August in the wood of the lower one-year old leader. Adults emerge throughout the late summer and fall seeking hiding places within the crown of the brood tree. There is little or no flying at this time or throughout the winter.

The weevil attacks the leader shortly before spring bud flush, thus killing two years of terminal growth, the one just starting and the one of the previous year. Trees up to 50 feet in height and 30 years of age are attacked. There is decided preference by the weevil for the longest leaders in the stand. Leaders shorter than 12 inches are rarely attacked with nearly all leaders more than 23 inches long attacked. Leaders seem to be attacked when the trees are about 5 feet tall, with high attack levels maintained until the trees are 40 to 50 feet tall.

When a terminal is killed, one or more laterals assume apical dominance. Damage is thus reflected in poor tree form due to crooks in the main stem as well as height and volume loss. Also, if other species such as hemlock and Douglas-fir are present, the attacked spruce will not be able to compete with the faster growth of its associates.

Reducing the impact of the weevil in susceptible stands through silvicultural practices has been studied. A few generalized recommendations can be made. One recommendation is to grow susceptible trees with very close spacing. This does not seen to reduce attack but it may improve tree form by forcing the laterals to assume dominance more quickly.

Chemical control has proved possible in several tests with the use of systemic insecticide.

## Douglas-fir Twig Weevil

The Douglas-fir Twig Weevil, (Cylindrocopturus furnissi), kills small branches of Douglas-fir reproduction. Damage seems to be more severe on open-grown trees or those growing on gravelly soils, during the period of drought, or other situations where the trees are under stress. Damage can be quite severe, deforming the trees and retarding their growth. Small trees, 5 feet high or less, may be killed outright. The insect has been a serious problem in Christmas tree plantations for some time. Trees larger than 20 to 25 feet tall are rarely attacked.

The adults are about 2.5 mm long with a typical weevil beak. The body is covered with intermixed light and copper colored scales. The egg is oval, pearly white and about 0.3 mm wide by 0.5 mm long. The larva is a white, legless grub, around 3 mm long with a brown head. The pupa is about 3 mm long, white, with obvious rudiments of beak and wing pads.

The Douglas-fir twig weevil overwinters as a larva in mines under the bark of twigs. Some adults may also overwinter in the tree crown. Pupation occurs in the pith of small branches in May and June. Adults emerge from mid-June through early August. Soon after emerging they feed upon small branches of Douglas-fir. About a month after emerging the adults begin ovipositing in branches and occasionally on the main stem. Most eggs are laid in the last 4 years of growth, but some eggs have been found on branches 10 years old.

Larvae hatch in August and September and start boring winding galleries between the bark and wood. One gallery can kill a small twig, but several galleries are needed to kill a branch or a small tree. Larvae and pupae will be obvious under the bark and within the pith on affected branches throughout most of the year. Since adults are around most of the year they can be beaten off the foliage on to a white surface.

Very little work has been done in attempting to control this insect. Systemic insecticides on an individual tree basis may be useful in reducing damage in the future.

## Insects Affecting Cones and Seeds

In the natural forest the impact of cone and seed insects is quite variable. Most tree species produce heavy seed crops periodically, the heavy crops being interspersed between years when seed production is light. This periodic production appears to have a profound effect upon insect populations that feed upon seeds and cones. When their food is scarce, the insect populations become low and generally when a bumper crop occurs, the number of seed eaters present is too low to destroy a large proportion of the seeds. Occasionally, however, there may be two successive "seed years". When this happens the seed insects may build up to high numbers during the first seed year so that the crop produced the following season may be almost completely destroyed.

The variation between the number and size of trees, acres, terrain and seed years makes management of cone and seed insects in natural forests difficult and relatively uneconomical. However, the increasing amount of forest regeneration work done in western forest regions has drawn greater attention to those insect pests attacking cones and seeds.

In recent years attention has been directed toward the improvement of tree varieties by selecting and breeding elite individuals either in seed production areas or seed orchards. Seed orchards lend themselves well to insect management.

Insect control in sound seed through pest management is achieved by: 1) prevention practices; 2) direct control using chemicals; and 3) an integrated approach using several methods.

Preventative methods include: 1) the establishment of seed orchards remote from, rather than adjacent to natural stands of the same species. In this way seed orchards are less likely to be infested by insects that occur in natural stands. 2) Delay the flowering time of trees by spraying with cold water or other methods. Most of the major seed-destroying insects lay their eggs in the spring when flowers of the host are being pollinated. Trees that flower earlier or later then normal are less susceptible to attack. 3) Removal of all cones from orchard areas each year may ensure that most harmful insects are removed and thus reduce the likelihood of severe attack the following year. 4) Protective screen wire cages around each cone can also increase the sound seed yield per cone.

Seed losses to insects in seed orchards or seed production areas can also be reduced with insecticides if preventive measures do not prove satisfactory. To date, best results have been achieved by applying systemic insecticides as granules or liquid around the base of each tree and foliar sprays or injections into the trunk.

The use of synthetic pheromones or attractants and blacklight trapping may also reduce insect populations. Then too, a combination of several techniques may be useful in a pest management system.

Destruction of seeds may be caused by insects that attack the buds, flowers, immature and mature cones, as well as by those that attack the seeds themselves. Cone and seed insects are representatives from a number of orders and families of insects. They include various species of beetles, borers, moths, maggots, chalcids, and true bugs.

CONE MOTHS - Larvae of moths from two families may be found attacking cones of fir, pine and spruce. The Douglas-fir cone moth (Barbara colfaxiana) attacks Douglas-fir and true firs. The small gray adult moths with speckled forewings emerge in the spring and lay their eggs on young tender budding cones. The yellowish-white caterpillars mine through scales and seeds making extensive resin-filled tunnels within the cone. Pupae overwinter near the cone axis and may remain in diapause for 1 to 3 years.

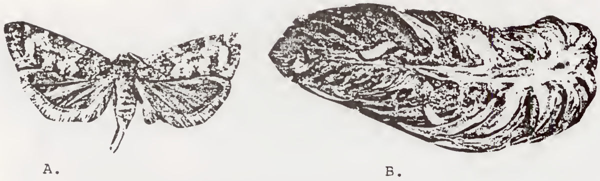


Figure 37. Douglas fir cone moth.
A. Adult moth B. Larvae inside cone

The ponderosa pine seed moth (Laspeyresia piperana) occurs through the range of ponderosa pine. Adult moths range in color from gray to black. The dirty-white caterpillars burrow through the central axis of the cone and mine the seed from the point of attachment. Larvae pupate near the pith. There is one generation a year but some larvae may remain in diapause for two or more years.

SEED WASPS - Seed wasps of importance in the Northern Region belong primarily to one genus, Megastigmus in the family Torymidae, order Hymenoptera. The Douglas-fir seed chalcid (M. spermotrophus) is widespread throughout the range of Douglas-fir. The adults are small ant-like wasps. The females have a long curved ovipositor which they use to drill a hole into young green cones to deposit their eggs. The larvae are small white legless worms which enter the seed and destroy the tissue within. Infested seeds show no evidence of infestation. Larvae may remain in the seed for 2 or 3 years before emerging.

CONE BEETLES - Eleven species of cone beetles are recorded from the western U.S. all belonging to the genus Conophthorus. Feeding within the cones by these beetles causes the cone to wither and die before it is half grown. The adults are reddish-brown to black and measure 2-4 mm in length. The adult bores into the base of the supporting stem of immature pine cones in the spring after the beginning of the second years growth. The female deposits her eggs along a tunnel formed along the main cone axis. The small legless grubs feed on the scales, seeds and tissues of the withering cones. Pupation and adult emergence occur during the summer and the adult overwinters in the dying cone. C. flexilis, the limber pine cone beetles and C. monticolae, the mountain pine cone beetle attack limber and white pines in the Northern Region.

Table 5. Summary of forest insect pests and their hosts

| Insect Species | Common Host | Occasional Host |
|---|---|---|
| BARK BEETLES | | |
| Douglas-fir beetle (*Dendroctonus Pseudotsugae*) | Douglas-fir<br>Western hemlock<br>Western red cedar | Western larch |
| Western pine beetle (*Dendroctonus brevicomis*) | Ponderosa pine | All pines |
| Mountain pine beetle (*Dendroctonus ponderosae*) | All pines | -- |
| Spruce beetle (*Dendroctonus rufipennis* [Kby.]) | Engelmann spruce | All spruces |
| Red turpentine beetle (*Dendroctonus valens*) | Ponderosa pine | All pines & other conifers |
| Pine engraver (*Ips pini*) and other species | Ponderosa pine | All pines |
| Fir engraver (*Scolytus ventralis*) | True firs | Douglas-fir |
| Douglas-fir engraver (*Scolytus unispinosus*) | Douglas-fir | -- |
| Douglas-fir pole beetle (*Pseudohylesinus nebulosus*) | Douglas-fir | -- |
| Pitch moths Various species | All trees | -- |
| BUD, SHOOT, AND TWIG INSECTS | | |
| Weevils: | | |
| Spruce weevil (*Pissodes strobi*) | Stika spruce | Other species of spruce |
| Other species of *Pissodes* and *Cylindrocopturus* | Other conifers | -- |
| Twig beetles: | | |
| Various species | All trees | -- |

|  |  |  |
|---|---|---|
| Shoot moths: |  |  |
| Various species | All trees | -- |
| Gouty pitch midge (*Retinodiplosis* spp.) | Pines | -- |
| ROOT INSECTS |  |  |
| Various species of white grubs, weevils, wireworms, and symphylids | All trees | -- |
| CONE AND SEED INSECTS |  |  |
| Various species of moths, beetles, weevils, midges, and wasps | All trees | -- |
| WOOD BORERS |  |  |
| Flatheads: |  |  |
| California flathead borer (*Melanophila californica*) | All pines | -- |
| Flathead fir borer (*Melanophila drummondi*) | Douglas-fir | True firs<br>Hemlock |
| Sculptured pine borer (*Chalcophora angulicollis*) | Pines, firs, Douglas-fir | -- |
| Golden buprestid (*Buprestis aurulenta*) | All conifers | -- |
| Western cedar borer (*Trachykele blondeli*) | All cedars | -- |
| Roundheads: |  |  |
| Ponderous borer (*Ergates spiculatus*) | Douglas-fir, Pines | Other conifers |

# CHAPTER VI

# RANGE INSECTS AND THEIR CONTROL

## Introduction

The impact of insects on rangeland ecology is not well understood. The insect fauna of rangeland is extensive and although numerous species might be classified as rangeland pests, they often go completely unnoticed until they reach an epidemic level. Countless reports have been written describing the widespread destruction caused by rangeland grasshoppers. Extensive research over the past thirty to forty years has been directed toward understanding the ecology of grasshoppers and devising new and effective control methods. Yet grasshoppers represent only one of hundreds of potentially damaging rangeland species. Root feeding insects, seed feeders, sap feeders such as grass bugs, aphids and leafhoppers as well as other leaf feeding species all can reduce range quality by killing plant stands outright, reducing plant vigor and quality or by prevention of reproduction by seed destruction. Why then is not more being done to identify and study rangeland insect species? By far the most important limiting factor is the comparatively low unit value of rangeland. Since rangeland forage is considered a low value crop, producers can afford little in the way of control methods. Consequently, rangeland entomology has been delegated to a low priority.

A survey conducted in 1970 of 14 western states concerning rangeland insect problems and control recommendations described clearly the current level of importance placed on this pest group. Three states contacted did not consider any rangeland insect pests as economically significant. Eleven states listed grasshoppers as the principal rangeland pest. Two states listed harvester ants, armyworms, cutworms and webworms as important pests. Other pests receiving mention included thrips, spittlebugs, Diptera and Hymenoptera.

The purpose of this chapter is to familiarize the reader with the key insect groups considered to be pests of rangeland. While numerous insect species may be considered rangeland pests at times, the cutworms, armyworms, harvester ants, grasshoppers and crickets are the most common targets for insect control measures.

## Grasshoppers and Crickets

Grasshoppers and Crickets, like most of the important rangeland insect pest groups, are foliage feeders. The insect Order Orthoptera includes the grasshoppers and crickets. The principal economic grasshopper species are placed in the family Acrididae (short horned grasshoppers) while the primary economic cricket, the Mormon cricket, is placed in the family Tettigoniidae. While there are some 618 species of grasshoppers described from U.S. rangeland, only a small percentage ever reach economic status. Those grasshoppers that feed on undesirable plants can be considered beneficial. All grasshoppers provide food for wildlife such as birds and small mammals and in that sense are beneficial.

Grasshopper species in the northern U.S. complete no more than one generation per season and some require two years to complete a single generation. In the majority of rangeland species egg laying occurs in the fall with winter passed in the egg stage. Low temperatures are required to break winter diapause and development continues with rising spring temperatures. Eggs hatch in May to July, with the nymphs developing through the summer. Adults mate and egg laying follows from late summer into the fall. A few species overwinter as nymphs, becoming adults in April or May. Eggs hatch in June and July and the partially grown nymphs overwinter. These species may become active in the winter when temperatures are favorable and commonly catch the attention of producers. However, since they usually do not occur in large numbers, these species are not considered economic.

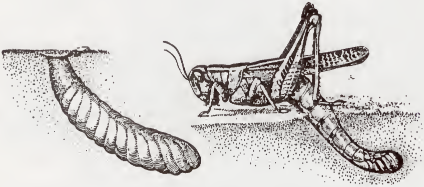


Figure 38. Egg laying by the two striped grasshopper, Melenoplus bivahatus

Grasshopper population density fluctuates, sometimes widely, from year to year. Since most species show a preference for specific plant groups, the economic loss caused by grasshoppers depends upon the grasshopper and plant species present. By considering the selectivity of grasshopper species for different plant types, three feeding categories can be delineated: grass feeders, broadleaf feeders and those that feed on both. Depending upon environmental factors and physiological changes in the plant, a grasshopper's preference may change during the growing season. This feeding variability coupled with the damage caused by other insects and rodents makes the assessment of grasshopper damage very complicated.

When populations of destructive grasshopper species are concentrated in an area, damage can be severe. Not only is there a direct loss from plant consumption by grasshoppers, but also an indirect loss attributed to their wasteful feeding habits. Grasshoppers feed much closer than livestock and may damage the growing tips of the plants. Seed heads may be destroyed by grasshopper feeding and extensive removal of vegetation by grasshopper feeding may lead to other problems such as soil erosion. A damage potential for grasshopper populations can not be accurately determined from population density figures alone. In years of adequate moisture, grass abundance on a range unit may be great. A healthy and vigorous grass stand can withstand much higher levels of grasshopper feeding before suffering an economic impact. Conversely, rangeland stressed by drought or overgrazing is not only more attractive to grasshoppers, but these areas can not withstand even moderate feeding damage.

Grasshopper outbreaks are a result of the interaction of a complex of abiotic and biotic factors. Rainfall and temperature during critical periods of the grasshopper life cycle over a two or three year period play a key role in population abundance. Grasshopper outbreaks do not follow a predictable cyclic pattern for a given area. Outbreak populations may remain at high levels for one to three years. In short, after over fifty years of study, entomologists have yet to find a method of survey or detection that will accurately predict the likelihood of specific grasshopper population levels for an area, state or region on an annual basis.

Much of the study and development of insecticides aimed at controlling rangeland insects grew from efforts related to grasshopper control. Early control efforts developed in the late 1800's made use of poison bait. The earliest record of baiting for grasshoppers occurred in 1878. Paris green, followed by several arsenic compounds and sodium fluosilicate evolved through the early 1900's. Aerial application of poison bait was first made in 1932, and continued through 1950. The discovery of the organochlorine compounds following World War II led to the use as such compounds as aldrin, heptachlor and dieldrin as sprays, baits and dusts.

The use of baits was discontinued for the most part in 1952 and testing demonstrated that chemical sprays were the most effective. Increasing environmental problems with chemical residues led to the discontinuance of the organochlorine compounds. They were replaced by organophosphate compounds such as malathion, parathion, and the carbamate carbaryl. Presently, malathion in a ULV formulation and carbaryl in an oil formulation are the principal insecticides used for rangeland grasshopper control.

Experimentation with a protozoan disease organism called Nosema locustae has led to the recent registration of the first biological insecticide for rangeland grasshopper control. The spores of this organism are mixed with a bran and spread by air over infested rangeland. Grasshoppers feeding on the bran ingest the spores and eventually succumb to the parasite. Nosema is specific to grasshoppers and crickets and therefore is much safer environmentally than chemical insecticides. However, the disease may be slow acting. It has been shown that carbaryl mixed with the spore bait will provide some immediate control while not reducing the long term effects of the disease organism.

The Mormon cricket, Anabrus simplex, is the principal cricket species of economic importance. Widespread destruction by this cricket can be traced in the West to the 1840's when crops of the early settlers in Utah became infested. Cricket outbreaks have been reported from some part of the Rocky Mountain region from 1914 to 1940. Infestations since that time have been lower and more localized. Since the Mormon cricket reportedly feeds on some 250 different range plant types, damage during an outbreak is usually severe.

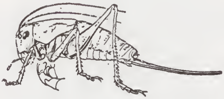


Figure 39. The mormon cricket.

Like grasshoppers, the Mormon cricket overwinters as a diapausing egg in the soil. Eggs hatch at lower temperatures than grasshopper eggs so the cricket nymphs are active earlier in the spring. One generation a season is typical. Mormon crickets are migratory and under favorable weather conditions will migrate to some extent each day from hatch till death. Mormon crickets persist in more or less permanent breeding areas in mountain ranges such as the Pryor Range in Montana. When conditions favor population increase, the crickets begin to migrate in bands since they are flightless. Migrating bands have been known to travel up to 1/2 mile per day or 25 miles in a season.

Mormon crickets were first controlled by the use of barriers or traps. Poisonous dusts and baits were used in the 1930's and 1940's. Chemicals such as aldrin, toxaphene and chlordane have been used in bait formulations and aerially applied. The last large scale cricket control program occurred in 1953 in Nevada. Only localized treatment projects have been required since, although the potential for widespread buildup is still present.

## Armyworms and Cutworms

Cutworms and armyworms cause their greatest impact on cereal and forage crops. The army cutworm and pale western cutworm are well documented pests of small grains throughout the Great Plains region, however, their impact on native rangeland is not as well quantified. There are many species of armyworms and cutworms that attack grasses and other range plants, yet only a few ever reach economic importance.

Cutworms and armyworms are placed in the insect Order Lepidoptera: Family Noctuidae. The larval stages (caterpillars, armyworms, cutworms) inflict the damage through feeding. The adults are dull colored, night flying moths. Life cycles of the various species vary. Some complete one generation per season while others complete two or more. Most of the common species found in northern climates complete one generation per season, overwintering either as larvae or eggs in the soil. Mating and egg laying occurs in late summer and early fall. Larval activity begins in the spring with warming temperatures and continues through May or June.

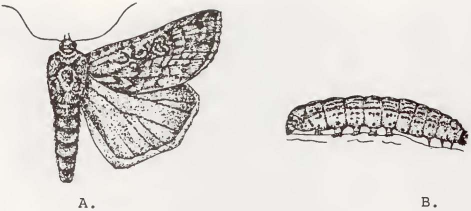


Figure 40. Varigated cutworm.
A. Adult moth B. Larva.

Cutworms and armyworms can be divided into four principal groups based on feeding habits: 1) surface feeding solitary cutworms - the black cutworm, bronzed cutworm and dingy cutworm are examples of cutworms that cut off plants near the soil surface, sometimes pulling the plant parts into their burrows; 2) climbing cutworms - typified by the variegated cutworm and spotted cutworm actually climb the stems of host plants to feed on buds, leaves or fruits; 3) army cutworms - like the true armyworm, fall armyworm and army cutworm usually occur in large numbers. These species are surface feeders preferring to feed at night and when populations are high they will move along the soil surface like an "army" in search of favored plant material; 4) subterranean cutworms - like the pale western cutworm, remain underground for most of their larval life severing plants below the soil surface and feeding on roots.

Control of armyworms and cutworms that are active early in the spring can be difficult. Chemicals offering long residuals that can be applied to grassland are no longer available. Shorter lived organophosphates and carbamate insecticides are often ineffective during these cool seasonal periods. These insecticides rely on the target pest ingesting treated foliage or absorbing the residues from treated soil or foliage. When temperatures are cool, cutworm activity is reduced, yet the insecticides continue to degrade. By the time the pest is active the chemical has dissipated. Subterranean species like the pale western cutworm are particularly difficult to control because they seldom if ever come to the surface to feed. There is currently research being done to find new chemical products that will offer the effectiveness of the long residual organochlorines but without their environmental impact. New types of bait formulations are proving to be effective. New chemical groups such as the synthetic pyrthroids are being investigated.

Preliminary results indicate they are effective at very low application rates, remain effective under cool conditions, and are effective against both surface feeding and subterranean species.

Harvester Ants

Harvester ants are common inhabitants of western rangeland and next to grasshoppers can be considered the most consistently injurious pest to rangeland. The harvester ants are grouped in the Order Hymenoptera: Family Formicidae: Genus Pogonomyrmex. The western harvester ant, P. occidentalis, is common throughout the western Great Plains. These ants are important because of the direct plant destruction they cause and through the collection of plant seeds. Their mounds are up to 12 inches high and surrounded by a barren area of up to 20-25 feet in diameter. Worker ants commonly harvest green seedlings in the spring and will damage established grasses and forbes as they continually try to enlarge the barren area surrounding the nest. Seeds of a large number of plants are collected by harvester ants. The seeds are a dietary staple for the ants although insect prey are taken if available. When seeds are abundant they are collected in volume and stored within the nest. During periods of wet weather, the seeds are removed from the nest to dry. Should they germinate they are discarded by the ants.

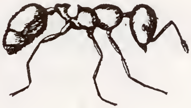


Figure 41. Western harvester ant.

The economic impact of the harvester ants is difficult to assess. While they unquestionably destroy plant life around their nest, the overall economic impact is debatable. Some authors argue that plant species are actually more widely distributed through the collection habits of the harvester ants. Seeds of the perennial grasses are commonly collected by the ants, however, since these grasses reproduce primarily by stolons, the impact of seed loss may not be critical. No accepted chemical control programs have been attempted. Many of the early control attempts included fumigation with carbon bisulfide. Later chlorinated hydrocarbons such as heptachlor, dieldrin, chlordane and toxaphene were applied as dusts with generally unpredictable results. In the early 1960's a new bait material called Mirex was developed primarily for fire ant control in southern states. Although it was tested successfully against harvester ants in Oregon, environmental problems developed with the compound and commercial use of the product did not develop.

# SECTION II

# WEED PESTS

# CHAPTER VII

# PRINCIPLES OF WEED CONTROL

## Introduction

Management of vegetation is basic to timber or grass production and wildlife, recreation, or water considerations. Modern land management objectives frequently involve capturing (or recapturing) as much of the site potential as possible in a desirable form of vegetation.

Forest management primarily involves measures to control forest species composition and to provide favorable growing conditions for preferred species. These may include: 1) measures to reduce shrub and unwanted small tree growth in preparation for forest regeneration, 2) treatments to release seedlings or saplings of desirable species from other competing species, 3) measures to regulate density (thinning) within stands of desired species, 4) measures to kill cull trees and trees of unwanted species in older stands, and 5) control of grasses or other herbaceous vegetation to prepare sites for conifer plantings.

Tremendous weed problems have been created on grazing lands by the introduction of exotic plant species or the shift of nonforage native species to positions of major importance. Changes in the vegetation communities of vast areas of range and noncropland are constantly occurring through the influences of grazing practices, cultural manipulations, plant introductions, diseases, insects, various other fauna, and many other environmental factors. In areas where vegetation is disturbed low value species may increase or become dominant. Economic losses from weeds on forage lands result from reduced forage value and productivity. Livestock productivity is also reduced as mechanical injury or poisoning increase.

Right-of-ways are the areas involved in common transport. The principal goal is to provide maintenance practices for the right-of-way vegetation that will economically ensure the protection, operation, stability, continuance, and safety of the common transport involved. Other goals of a vegetation management program are: 1) naturalization of the right-of-ways to the extent desirable with adjacent land areas; 2) encouragement of regeneration of natural vegetation indigenous to the area; 3) making right-of-ways appear to be more of a natural entity blending into its landscape; 4) reduction of maintenance costs; 5) improvement of aesthetics; 6) reduction of erosion and water sedimentation; and 7) provision of strips of natural area for wildlife whenever possible.

In all cases of weed control, it is important to consider weeds declared "noxious" under state or local regulations. Certain weeds must be controlled due to their capabilities for reproduction and invasion into agricultural lands and subsequent negative impacts.

## Classification of Weeds

Recognition of grassy and broadleaf weeds is important because they differ in reaction to herbicides, cultural aspects, desirability and method of control.

For weed control purposes, plants can be divided into three main categories - grass, broadleaf or woody.

> Grass plants have one seed leaf. They have narrow, upright, parallel-veined leaves and fibrous root systems.
>
> Broadleaf plants have two seed leaves. They have broad, net-veined leaves and tap roots or coarse root systems.
>
> Woody plants include brush, shrubs and trees. Brush and shrubs are regarded as woody plants that have several stems and are less than 10 feet tall. When trees are present, brush or shrubs may be understory. Trees usually have a single stem (trunk) and are over 10 feet tall.

Growth habits of weeds are important to understand so timing of control methods can be as effective as possible.

> Annuals complete their life cycle from seed in less than one year. Some weeds are specifically winter or summer annuals while others are adapted and can germinate and grow in either the fall or spring.
>
> Winter annuals germinate in the fall, overwinter, mature, set seed and die in the spring or early summer. Control is most effective during the seedling stage in fall or early spring.

Summer annuals germinate in the spring, grow, set seed and die before fall. Control is most effective soon after germination in the seedling stage of growth.

Biennials complete their life cycle within two years. The first year the plant forms basal leaves (rosette) and a tap root; the second year it flowers, matures and dies. For best results, biennial weeds should be controlled in their first year of growth.

Perennials live longer than two years, many may live almost indefinitely. They reproduce by seed and most spread and reproduce vegetatively. Perennials are difficult to control due to their persistent root systems. The most effective control measure is to prevent establishment of perennials. On established stands of perennials, control methods should be adjusted to the yearly growth cycle of the species involved. Control is most effective during the fast growth period prior to flowering or during regrowth after cutting.

Simple perennials spread by seed, crown buds and cut root segments. Most have large, fleshy taproots.

Creeping perennials spread vegetatively as well as by seed. Grass plants generally have a shallow root system compared to the deep root system of broadleaf plants.

Certain perennials reproduce vegetatively from underground bulbs or tubers. Many of this type also produce seed.

Brush, shrubs and trees may spread vegetatively as well as by seed. Woody species differ in susceptibility to various control measures. Manual and mechanical means are not effective for the control of sprouting species. Other species differ in their susceptibility to various herbicides and timing of control. As a general rule, most species are most readily controlled with herbicides when they are in the rapid growth stage.

## Methods of Control

For a weed control program to be successful, weeds or undesirable plants must be destroyed without damaging crops or desirable plants. The most effective or economical method or combination of methods for weed control depends upon the situation. Herbicides are a supplement to good cultural and management practices but are not a replacement for them.

Methods that can be used for weed control include: 1) prevention; 2) cultural control; 3) mechanical control; 4) biological control; and 5) chemical control. Although chemical control is often thought of first, it is not a cure-all for all weed problems. Alternative and integrated approaches to control should always be considered and causes of weed problems should be identified and corrected. Good farming and land management practices should be first in any weed control program.

1. Prevention is the most practical method of controlling weeds. If weeds are not allowed to infest an area and seed is not produced, there is less chance for weeds to become established. Once weeds are established they are difficult and costly to control and may persist for many years as dormant seeds in the soil.

   Preventative control measures should be adapted where practical and include: 1) the use of clean seed; 2) cleaning all implements, vehicles, harvesting and mowing equipment before moving it from infested areas; and 3) keeping irrigation ditches, fence rows, roadside and other non-crop areas free from weeds.

2. Cultural control includes sound vegetation management practices that reduce the risk of invasion and increases in weed species. The use of silvicultural systems, such as tree stocking rates, conifer species and site potential relationships, and use of natural regeneration versus planting, influence impacts by undesirable plant species.

   Sound range management practices provide an opportunity for desirable vegetation to become more competitive and thus reduce weeds or prevent weed invasion. Proper stocking rates and season of use by livestock reduce impacts from weeds on rangeland.

   Crop competition can be the cheapest and easiest method of controlling weeds. A crop will flourish if it can compete more efficiently than weeds for sunlight, water, nutrients and space. If the crop is established before the weeds germinate, it will often crowd out the weeds.

3. Mechanical control involves variations on two wellknown weed control techniques: tillage and mowing.

One type of tillage is burial of unwanted vegetation. This is effective on most small annual weeds. All plant parts must be buried for this method to be effective. Burial is only partially effective for controlling perennials capable of sprouting.

The second important method of tillage is to disturb rooting systems. This is achieved through cutting or pulling root systems. This is most effective in hot, dry weather under dry soil conditions.

Both tillage systems are employed with some timber harvest methods. Methods which scarify or disturb the soil either by means of the equipment or pulling logs across the soil may provide a mechanical control. Unfortunately, soil disturbance may create other serious problems such as an increase in erosion.

Mowing has been used in some wildlife situations. It has proven to be most effective for control of tall-growing species. Plants are mowed to reduce competition with the desirable species and to prevent seed production. Annual weeds are often mowed to control seed development. Repeated mowing is needed to starve underground parts of perennial plants. Mowing does not work well on plants that resprout from the base.

The most effective phenological period to use either mowing or tillage is when the root reserves are at a low ebb. For most species this is the period between full leaf development and flowering.

4. Biological weed control is the use of a living organism to control weeds. Insects are the most commonly used agent but fish, nematodes, snails, fungi and bacteria offer additional organisms for controlling plants.

   Biological control can be useful for suppression of unwanted plants, generally in a non-crop situation. It is important to remember that the development of a biocontrol agent is time consuming and expensive. Research is needed to find host specific agents. Often several different agents are needed to give economic control of a weed species. Biological control is not recommended in cropland situations due to a lack of adequate economic threshold data for weeds. In a field situation, there are usually several other weed species that will fill a void left by the plant taken out by a biological control agent.

5. Chemical control, use of herbicides for weed control, is used on a large scale in Montana. Research over the past few decades has produced increased knowledge and many new chemicals for use in weed control. Chemicals are now widely used and will continue to play an important role in forest, range, and right-of-way weed control.

# CHAPTER VIII

# CHEMICAL WEED CONTROL

## Classification and Types of Herbicides

### Classification by Use

Selective herbicides kill some plant species when applied to mixed populations without serious damage to other species.

Nonselectives chemicals are generally toxic to plants without regard to species. Remember, plants differ in susceptibility to any specific chemical and the choice of herbicide and application rate depends on the species to be controlled.

### Classification by Mode of Activity

Contact herbicides (foliage applied) control weeds by direct contact with plant parts. They are referred to as chemical "mowers", as only the plant area contacted is controlled. Good coverage is necessary.

Translocated herbicides (foliage applied) are of major importance in the control of weeds, particularly for those plants with underground reproductive organs. Herbicides are translocated within the plant through the food stream (symplastic system - phloem), the water stream (apoplastic - xylem), or intercellular system. Most herbicides with free mobility are translocated via the water stream (atrazine, diuron, etc.). A few are translocated in both food and water, (amitrole, picloram, dicamba) and a very few in the food stream (fenac). They accumulate in and affect active plant growth centers. In general, these compounds are selective. Some are effective in the soil and can be taken into the plant through the roots. They are most effective when applied to the plant foliage.

Root or emerging shoot-absorbed herbicides (soil applied) are referred to as the residual herbicides. The length of time the soil remains relatively weed-free depends upon the chemical used, amount applied, rainfall, soil type and the plant species invading the treated area.

Compounds used selectively in some situations may be nonselective when the rate of application is increased. Soil residual herbicides generally have little effect upon plants when sprayed on foliage. They are most effective when absorbed through the shoot or root and moved in the water stream of the plant to the leaves.

## Herbicide Formulations

Most chemicals used as herbicides must be combined with a liquid or solid carrier to be distributed uniformly during application. The formulation of a chemical is the manner in which the active ingredient and the carrier are mixed.

Some common types of formulations include:

### Dry Formulations

Dusts are finely ground chemicals that may or may not be mixed with a diluent.

Granules (G) are inert, coarsely around carriers, such as clay, with herbicides impregnated on them. Often they must be soil incorporated to be effective.

### Liquid Formulations

Water soluble concentrates (WS) form a true solution in water, requiring little agitation.

Emulsifiable concentrates (EC) are dissolved in a solvent along with emulsifiers. This mixture forms a milky-looking emulsion in water and requires moderate agitation.

Liquid suspensions (L) are a concentrated suspension of a wettable powder (WP). Fine particles are suspended in a liquid concentrate which disperses readily in the spray tank. Constant agitation of the spray mix is required.

### Special Formulations

Oil solubles are those herbicides soluble in an oil diluent.

Emulsions are two liquids held together by a third chemical or emulsifier. Emulsions are usually either 1) oil in water (o/w) - the more common type, or 2) water in oil (w/o) - called invert emulsions.

### Drift Control

Thickeners
Foams

## Timing of Herbicide Treatments and Rates

The timing of herbicide treatments depends on the herbicide and its persistence, desirable species tolerance, characteristics of target species, cultural practices, climate, and soil conditions. Three categories of timing are recognized: preplant (usually agricultural), preemergence, and postemergence. The herbicide rate is determined by label direction and use experience.

Preplant treatments are made to the soil before the crop is planted. Typical preplant treatments are applied after seed bed preparation and directly before planting the crop, such as with site preparation.

Preemergence treatments are made to the soil before the crop weeds have emerged.

1. Contact preemergence is an application made after weed emergence but prior to crop emergence.

2. Residual preemergence is an application which kills weeds as the seed germinates or as they emerge either before or after the crop has emerged.

Postemergence herbicides are applied to the soil after the crop or the weeds have germinated and started to grow. Postemergent applicators are used frequently in conifer release sites.

## Factors Affecting Chemical Weed Control

### Stages of Growth

Weeds go through four stages of growth: seedling, vegetative, flowering and maturity. There is a best stage for weed control. If control is not obtained at the best stage of growth, the method of control may need to be changed.

Seedling - The seedling stage of growth is the same for annual, biennial and perennial weeds. They are all starting from seed. The weeds are small and succulent, therefore less energy is required for control at this stage of growth than any other. This is true whether the method be mechanical, chemical, or management.

Vegetative (annuals) - The vegetative stage of growth is when energy being produced by the plant is going into the production of stems, leaves and roots. Control at this stage is still feasible but more difficult than at the seedling stage of growth.

Flowering (annuals) - At a certain stage of growth and time of year, a chemical messenger formed by the plant tells it to change from the vegetative to the flowering stage of growth. At this time most of the weed's energy goes into the production of seed. Chemical control at this stage, for both grass and broadleaf, is more difficult.

Maturity (annuals) - Maturity and seed set of annuals complete the life cycle. Chemical control is not effective at this stage. (See Figure 1.)

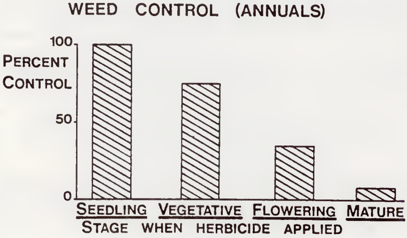


Figure 1.

This chart shows expected control of annual weed from control efforts at various stages of plant growth. Best results are obtained by treating annuals at the seedling stage of development.

Biennials - Biennials require two years to go through the same stages as annuals. Control is similar at each stage.

Seedling (perennials) - The seedling stage of growth and its control is the same as for annuals and biennials. However, the stages of growth from vegetative through maturity are different.

Vegetative (perennials) - Part of the energy used in the production of stems and leaves for the vegetative stage of growth is derived from energy stored in the underground roots and stems. Other energy comes from production in the plant leaves. Chemical control is mediocre at this stage of growth.

Flowering (perennials) - Again, as with the annuals, a messenger is manufactured by the plant at a certain time and stage of growth. The plant's energy then goes into the production of flowers and seeds. Food storage in the roots is initiated and continues through maturity. Chemical control is effective just prior to flowering (bud stage).

Maturity (perennials) - For these plants only the aboveground portions die each year. The underground roots and stems remain alive through the winter months and send up new plant growth the following spring. Chemical control is not feasible at this stage. (See Figure 2.)

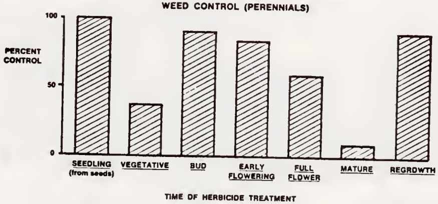


Figure 2.

This chart shows the expected control of perennial weeds from a herbicide application at the various stages of growth. Best control is obtained by treating perennials at the bud or regrowth stage. This causes the greatest drain on the underground food reserves. Treatment at early flowering almost equals that obtained at the bud stage of growth. When perennials reach full flower, control drops off. It is also beneficial to treat the regrowth.

Control programs are conducted primarily during late spring and early summer, however, fall treatments are possible under some conditions. Herbicides will reach the underground plants parts through the natural translocation activity of certain plants. In the fall, nutrients are moved from the aboveground parts of the plants in advance of the first killing frost to be stored over winter in the underground parts. Perennial weeds are most susceptible to herbicides during the fall regrowth (Figure 2). Underground parts must be killed to achieve control of these weeds.

Biennials, plants which develop from seed the first year, overwinter in a rosette stage, to flower and cause problems the following year, also can be controlled by a fall application. The rosette stage is an ideal time to control many biennial species.

Also controlled by a fall application are winter annuals which germinate in the fall, grow through the winter and flower in the spring or early summer.

With a fall application of an herbicide, the susceptible target plants have to survive three stresses in a row: 1) herbicidal effects, 2) winter effects, 3) effects of the heavy demand for nutrients caused by the rapid growth period in the spring.

### Foliage application

Foliage applications are affected by the location of the growing point, how the herbicide will enter the weed and the size and species of weed to be controlled.

Grass - A seedling grass has its growing point below the soil surface. Control is more difficult when the growing point is protected in this manner. With deeply established species neither herbicides nor cultivation may reach the growing point and the plant regenerates. Creeping perennial grasses have protected buds below the soil surface.

Broadleaf - Growing points and regrowth of broadleaf plants are different from those of grass plants. Seedling broadleaf weeds, in contrast to grass weeds, have an exposed growing point at the top of the young plant. They also have growing points in the leaf axils. Herbicides can reach these points more readily and cultivation will control the plant easily. The perennial broadleaf plant is difficult to control because of the many buds on the creeping roots and stems.

Woody - Many woody plants, either cut or uncut, will sprout from the base or roots.

Leaf Shape - Differential foliar wetting affects herbicide selectivity. On plants with narrow vertical leaves the herbicide spray solution tend to bounce or run-off. In contrast, broadleaf plants with flat, wide leaves, tends to retain the spray solution. Retention of spray solution is important.

Leaf surface (wax and cuticle) - It is important for the chemical to penetrate the weed leaf surface. Thickness of wax and cuticle are factors partially governing entrance of a herbicide into a leaf.

A leaf with a thin cuticle has good contact between the spray solution and the leaf surface. In contrast, on a leaf with a thick, waxy surface the spray solution tends to stand up in droplets with poor leaf contact.

Wax and cuticle are less thick on young weeds. Best results are obtained by treating with herbicides at the early growth stage.

Leaf surface (hairs) - Other factors that tend to keep the spray solution from entering the leaf are important. On a weed leaf with hair on the surface, the droplets tend to stand up on the hair and are not in contact with the leaf surface.

Some weeds are hairless, others have many and varied hairs. Generally there are fewer and shorter hairs on seedling weeds compared with the older stages of growth.

## Soil Application

Soil applications of herbicides are affected by chemical and physical properties of the herbicide and soil and their interactions.

Herbicide characteristics and soil particle tie-up - Herbicides have different properties. One of the properties is ionic charges. Chemicals applied to the soil vary and are from non-charged to strongly charged. Those without a charge tend to leach through the soil profile more readily. Others, with charges, tend to tie-up on the negative charge sites of soil particles.

Solubility - Another property is solubility, or the ability to dissolve in water or the soil solution. Herbicides vary from insoluble to soluble. Solubility is somewhat related to movement in the soil.

Leaching - Leaching, movement of a herbicide through the soil, is related to herbicide characteristics and soil factors. Herbicides and soils vary from non-leachable to completely leachable.

Persistence - Persistence of a herbicide in the soil is governed mainly by the chemical's properties, rate of application, precipitation, temperature and the soil's properties.

Soil type - Some herbicides are applied to the foliage of weeds. Other herbicides are soil-active and are applied to the soil surface. Several soil characteristics are important in herbicide movement. These include texture (sand, silt, and clay) and organic matter content.

Sand is course and does not have many charge sites. Herbicide molecules move through the soil profile readily.

Clay is fine and has many charge sites. The herbicide molecules move through the soil profile and attach to the charge sites on the clay particle. Herbicides tend to be more persistent in clay soils.

Organic matter has many more charge sites to tie up herbicides than any of the above soil types. Herbicides, as well as other charged particles such as water, sodium, calcium and ammonia, are bound tightly in soils high in organic matter.

Salt content of soils, increased by snow and ice control, increases the activity of soil residual herbicides. In solid with high salt content, lower herbicide rates may give acceptable control.

## Climatic factors

Climatic factors, such as temperature, humidity, precipitation and wind will all influence herbicide activity and weed control results.

Temperature - As the temperature increases, the effect of the herbicide activity speeds up. Weed control results are the same, regardless of temperature. However, the number of days taken to see the full effect is changed by temperature.

Humidity - Approaching 100 percent humidity, a foliar-applied herbicide will enter the leaf more easily and rapidly than at low humidity where penetration is slow. At high humidity, the weed leaf is more succulent, has less wax layer and a thinner cuticle.

Precipitation - Rainfall is an important factor in weed control. Precipitation, occurring after a foliar-applied herbicide treatment, may decrease effectiveness as a result of removal from the leaf surface.

Rain will activate soil-applied herbicides. But is can also move the herbicide through or from the target area. It is difficult to hold the herbicide at the edge of intense run-off areas due to flushing and leaching action of surface run-off water.

Herbicide characteristics, soil texture, organic matter, precipitation and surface flow determine chemical persistence. Herbicides can remain concentrated at the soil surface, partially leach (diluting effect) or move through the soil in a concentrated front. When the herbicide moves through as a concentrated front, new weeds may grow above.

Wind - Wind can cause spray drift as well as move dust-laden herbicide particles.

Wind and temperature - Wind and temperature can also affect the weed. A hot, dry wind will cause plant stomata to close, leaf surface to thicken and wax layer to harden. These factors make foliar herbicide penetration more difficult.

### Woody plants

Woody plants can be controlled either mechanically, by use of fire or chemically. However, some woody species re-sprout readily following mechanical controls and use of fire. Therefore determination of woody species composition is important prior to any control program.

Foliar spraying - Herbicides are applied to the foliage of woody plants. Spraying woody plants at a young stage of growth provides the best results.

Basal spraying - Herbicides are applied in oil to lower parts of stems and crowns. For large stems, best results are obtained by cutting and treating the stump.

Stump treatment - Close cut stumps and root collars may be treated with basal spray mixtures. Best results are obtained by treating immediately after cutting. All sprouts must be treated.

Soil treatment - Applications are made to the base of plants. Generally, herbicides in the pellet form are used. These must be activated with precipitation for results to occur.

## Herbicide Application Equipment

### Types and Classes

The equipment used is of two general types, airborne and ground. The airborne equipment is either carried by fixed wing aircraft or helicopter. Each has special advantages for certain types of weed control and should be selected accordingly. Speed, cost control and ease of access to difficult and remote areas are advantages of airborne equipment. Difficulties involve trouble getting the material on target, drift problems, flight obstacles and safety.

Operational preplanning, including application area mapping, sensitive area marking, flight obstacle identification, pre-application flyover and other information specific to the area being treated, is essential to the practical use of this equipment.

There are several types of ground equipment. Some is hand carried, such as back pack sprayers or duster hand sprayers. others are mechanized and drive across the area to be treated, such as hydralic sprayers or air sprayers. For more complete information on types of equipment and proper care please refer to the Basic Pesticide Equipment Manual.

Both airborne and ground equipment are classified according to the type of material used: conventional (water in water, oil in water, and oil in oil), invert (water in oil), and granular.

## Application

Proper application is an absolute requirement in obtaining satisfactory results from any herbicide treatment. All treatments must be applied uniformly at the recommended rate over the area or onto the species to be treated in a timely manner.

## Drift

A principal concern in the use of herbicides is containment. The operator must know what the target is, be able to identify it, get the material on target at the right time and in the right amount. Damage has resulted from direct off-target hits (not drift) caused by operator carelessness, lack of knowledge or accidents or from the application of incorrect rates and chemicals. Steps must be taken to avoid misuse.

The term "drift" refers to the movement of herbicides through the air to off-target areas. It presents a potential hazard to sensitive vegetation (crops, gardens, ornamentals) adjacent to or on the target area.

### Drift Occurrence

Particle drift - At the time of application, small spray droplets can be carried by air movement from application areas to other areas. The distance a particle of herbicide spray can drift is determined by one or more factors: 1) the force of an existing crosswind; 2) the distance from the spray nozzle to the ground; and 3) the size of the particle itself. Particles smaller than 150 microns (fog or mist) present the greatest drift hazard.

Vapor drift - This form of drift results from the tendency of chemicals to vaporize. The movement of such vapor with wind currents may cause injury to sensitive vegetation. Vapor drift has less likelihood of occurring than does particle drift, but if vapor drift does occur, it has more potential for distance.

## Control Measures

Use the lowest pressure possible.

Leave an untreated edge.

Angle nozzles toward the ground, slightly forward in the direction of travel.

Use the largest nozzle orifice as possible for the rate and pressure required.

Use less volatile formulations of the chemicals.

Spray when wind speed is low.

Do not spray during a temperature inversion.

Avoid sensitive vegetation.

## Drift Control Agents

Adjuvants and application systems have been developed which help overcome certain drift problems that exist in conventional spraying. Three of these systems are: foams, invert emulsions and spray additive stabilizers (thickeners).

Though different in method, there are similar advantages in all three: better drift control (physical and volatile) and more highly visible spray (better placement).

# CHAPTER IX

# WEED CONTROL IN FORESTS

## Introduction

Planned management for increased productivity of forest products is essential to meet the needs of a rapidly growing population. The purpose of forest management is to provide favorable growing conditions for preferred species. Weed and brush control is also needed to maintain forest roads and trails for recreational and resource purposes.

Practically all forest-tree species are unwanted in one situation or another and become the subject of control efforts. Trees of even the choicest species are killed in thinning and stand-improvement operations. Hardwoods and shrubs are weeds in areas where pure stands of pine or other conifers are the objective. Hardwood stump sprouts are weeds where seedling regeneration is desired, even though the species may be the same.

Shrubs and hardwood species fall in the weed category more often than conifers because of their sprouting characteristics and because the successional trend is toward these plant forms on many relatively poor sites where pines would yield more profitable commercial timber. At present, broadcast methods for selectively controlling unwanted species in such forests are not available. Only a few tree species rate so low in commercial value that they are considered weeds in all forest situations. A number of hardwood species that never attain more that shrub or small-tree stature present weed-control problems if they interfere with natural or artificial regeneration.

Forest tree nurseries present another weed control situation that differs from other plant cultures. Seedlings of a single species are grown at relatively high densities. Often weeding is done by hand or cultivation, but if effective chemicals are available, weed control costs can be cut dramatically. The troublesome weeds in forest nurseries are, for the most part, the usual annual broadleaf and grassy weeds of cultivated fields and gardens. The intensive culture that is practiced in nurseries generally precludes establishment of perennial weeds.

All weed control efforts in forest areas must also consider those weeds termed noxious by state and local governments.

## Site Preparation

Land that needs planting to restore it to timber production is normally covered with brush competitive grasses, and some weed species such as spotted knapweed or small trees of inferior species or quality. Conifier sites planted without some form of prior treatment to eliminate severe competition can hardly be expected to survive. This is referred to as preplant or site preparation.

Measures taken prior to planting meet one or more of the following objectives: 1) removal of brush or herbaceous cover that interferes with the performance of planted stock, 2) reduction of physical obstacles to planting, and 3) scarification of ground surface to provide a more favorable seedbed for direct or natural seeding.

Mechanical methods of site preparation have some advantages over the use of herbicides in certain situations. Such methods not only remove undesirable vegetation but prepare the soil and site for reforestation. Herbicides can kill undesirable vegetation, but the dead vegetation may have to be removed by mechanical equipment or by burning to prepare the soil for seeding or planting.

A variety of machines have been designed or adapted for mechanical brush removal. Tractors equipped with ordinary bulldozer blades or with toothed brush blades are usually employed in clearing brushlands on pumice soils in eastern Oregon. Other equipment that may prove useful against some types of brush are brush beaters or choppers such as the bushwhacker, railing and cabling devices, brushland plows, root planes and root plows, and tractor-mounted saws and mowers. On suitable soils and terrain occupied by susceptible species, mechanical site preparation does an effective job of killing brush and preparing soil for planting or seeding. Unfortunately, large areas of forest land that must be reclaimed consist of steep, rocky sites where mechanical equipment cannot be used effectively. Other large areas are occupied by resprouting species that recover following mechanical control effects.

Herbicide effectiveness in site preparation against shrub species varies considerably. The most widely used herbicides are low-volatile esters of 2,4-D. Other chemicals used on selected species include dichlorprop, amitrole, hexazinone, glyphosate, triclopyr and amitrole-T. Low-volatile esters of the phenoxy herbicides are generally prescribed in forest land spraying. They give consistently good results and minimize volatility hazard.

Aerial spraying is generally used to apply herbicides on forest lands, since this method of application is effective, inexpensive, and suitable to mountainous terrain and areas inaccessible to ground-spray equipment. Basal-trunk spraying, mist blowers and cut-surface treatments are used on limited areas and for special purposes, but these methods are more expensive.

Control burning also is used to clear dense stands of brush and prepare sites for seeding and planting. To prepare brushlands for burning, shrubs may be killed with herbicides or crushed with mechanical equipment. Dried, treated brush may be burned, but green brush will not burn. Caution must be exercised, however, for dry brush forms a hot, flashy fuel that burns explosively. Burning should be carried out only by competent personnel having adequate fire-control equipment. Wide, well-cleared fire lines should be provided around the area to be burned.

One disadvantage of burning is that the heat may induce germination of dormant brush seeds in the soil or create conditions favorable for germination of others. Burning may thus result in a new stand of brush seedlings that require treatment at additional cost to insure survival and growth of planted or seeded conifers.

Almost invariably, when mechanical methods or burning are used to clear brushlands, intelligent use of herbicides can supplement the primary brush control, improve the degree of control, insure a longer-lasting effect and safeguard the investment. Aerial applications of herbicides have been used to control brush sprouts and seedlings after burning or scarification with mechanical equipment.

Before a plantation or direct seeding of conifers can be considered fully established, it must have reached the stage where it has no obvious competition for light and growing space from deciduous trees, brush and herbs. In other words, conifers must be free to grow unimpeded by other species that are taller or potentially equal in height and development.

## Control During Establishment

Duration of the establishment period of forest species is almost entirely dependent on the habits of competing vegetation. A conifer that would be free to grow if still alive after two years in a grass-forb cover might still be in danger of suppression in the vicinity of fast-growing shrubs or trees. Undesirable species should be classified according to their effect on the environment of the crop species, and measures for control should be planned accordingly.

Weeds that offer competition primarily for moisture, without seriously shading or matting newly planted seedlings, usually do not require control for more than a single year. Soil applications of atrazine normally exert a substantial influence in the early-season development of weeds, even during the second season after application. Two seasons of development without serious moisture stress often are adequate for establishment of conifers under relatively severe conditions. Once established, conifers dominate herbaceous weeds.

Shading and mechanical action of woody associates on planted conifers are just as important as moisture depletion. Conifers grown beneath a heavy overstory tend to have spindly stems that are too weak to prevent matting by deciduous foliage or clipping by animals. The use of herbicides enhances the growth rate of saplings. Control measures sufficient to bring seedlings to dominance must, at the very least, suppress the overstory enough to allow underplanted conifers to keep pace with overstory recovery. Conifers usually reach their most rapid growth in height somewhat later than their hardwood associates. Release sufficient to keep conifers from being suppressed during the first five years after spraying should eventually bring about their dominance. More drastic control of brush usually is not justified for reforestation alone.

Selection of measures to achieve dominance of conifers in various brush types depends on the sensitivity of crop species to chemicals needed to suppress brush, the duration of beneficial effects from individual treatment and the cost of treatment per crop tree. Sensitivity of crop trees may limit the severity of treatment permissible for the brush. Moderate damage to crop trees is sometimes justified to provide necessary brush suppression. In other instances, heavy treatments that produce no evident damage to conifers may be unnecessarily severe and costly in terms of brush control. Subtle reduction of growth in conifers may persist over a prolonged period. The balance is nearly always delicate and treatments should be applied only to those areas where crop trees are alive in reasonable numbers and control of brush or weed trees will have a clearly beneficial influence. Sometimes two treatments at low rates are justified, particularly on very productive sites.

Before the development of herbicides, plantation release was carried on by hand methods. Grasses and herbs were controlled with tools such as hoes, grub hoes and mattocks. Woody plants were controlled with cutting tools such as the brush scythe, corn knife, brush hook and machete. Hand methods still have a place in small areas, but on large tracts herbicides provide better control, are faster acting and more economical.

It should be pointed out the the manager of wild lands has a different concept of vegetation control than the manager of agricultural lands. The forester generally does not require eradication of all competing vegetation. Instead, his goal consists of giving competitors enough of a setback that the coniferous crop can move ahead of the competitors and eventually crowd them out. Since such an approach is less costly than killing all plants, it fits in well with the relatively low financial returns available from such wild lands.

It cannot be over emphasized that certain noxious weeds, such as leafy spurge and Canada thistle, which are highly competitive, spread rapidly and can invade new areas should be controlled on forest lands. In some instances these weeds, while not causing serious problems in forest lands, can be of extreme importance in nearby agricultural lands.

## Established Stands

Silviculturally, "release" or "weeding" operations are designed to retard the growth of competing undesired species, thus releasing the favored species with little damage. Prior to the advent of herbicides, cultural treatment employed mechanical techniques such as hand cutting of small hardwoods and conifers, girdling of larger stems by cutting through bark and cambial layers at a convenient height around the stem, and controlled burning. Mechanical methods are effective in killing tops or removing aboveground parts of existing stems but frequently result in profuse sprouting from the root-collar zone of some hardwoods. This may aggravate the competition problem both above ground for growing space and below ground for moisture and nutrients. Furthermore, hand cutting of individual undesirable trees is prohibitively expensive if they are abundant.

### Foliar Applications

Since the advent of modern herbicides, aerial spraying has become a common method used to release conifers from brush competition because it is an inexpensive method for applying herbicides in very rough or mountainous terrain. Basal spraying, mist blowers, and other more laborious methods have been used on only a small fraction of the acreage treated to date. Volumes of spray applied usually range from 4 to 10 gallons per acre, depending on species, height and density of the shrub cover and on the season, carrier, relative exposure of conifers and degree of control desired.

Herbicides for conifer release must be used with care in order to reduce potentials for conifer damage. Selectivity can be increased by timing of application, rate of application and herbicides used. Low-volatile esters of 2,4-D are the most commonly used chemicals for release treatments.

Foliar applications in mixed hardwood-conifer stands are often made in early summer to coincide with full leaf development in hardwoods and hardening of new growth in conifers. However, this varies with species and region. Douglas-fir [Pseudotsuga menziesii (mirb.) Franco] is more resistant to 2,4-D than is ponderosa pine [Pinus ponderosa Dougl.]. Western hemlock [Tsuga heterophylla (Raf.) Sarg.] is intermediate in susceptibility between Douglas fir and ponderosa pine. During susceptible periods, injury to all conifers is greater when herbicides are applied in oil or in oil-in-water carriers.

Conifers display a seasonal variation in susceptibility to herbicides. Douglas-fir suffers injury when sprayed during the growing season but is relatively resistant to 2,4-D in early spring and early fall. In contrast, ponderosa pine is damaged during spring and summer but becomes resistant in fall. Degree of control is dependent on the quantity of herbicide translocated to various plant parts and the physiological state of the plant. Actively dividing meristematic tissue is most vulnerable. Satisfactory results in killing both tops and roots are obtained by slow penetration into the leaves, resulting in a slower death of the leaves and maximum translocation to root systems. Rapid killing of above ground plant parts with over applications will reduce translocation to roots. Adventitious buds that survive can sprout thus reducing the effectiveness of the control. When only the tops are killed on existing hardwoods, or profuse sprouting occurs, additional foliage treatments may be required for adequate conifer release.

### Basal or Basal-Bark Treatment

In contrast to broadcast foliage application, basal or basal-bark treatment is an individual-stem treatment used for selective control of low-density scattered hardwoods or shrubs in any season of the year. Treatment is usually restricted to standing trees under 4 inches in diameter or to sprout clumps arising from previously treated stems. The spray solution is applied under low pressure directly to the bark surface above the groundline. The lower stem is thoroughly wetted with excess rundown on all sides to assure coverage of the root-collar zone. There is some upward movement of herbicide but little lateral movement or downward translocation into the root system. This method, properly applied, effectively girdles the stem and kills dormant buds in the root-shoot transition area, thereby suppressing sprouting and eliminating the need for retreatment.

### Cut-Surface Treatments

Cut-surface treatments are a combination of mechanical and chemical techniques. They are selective individual-stem treatments applicable in situations involving relatively small numbers of scattered trees, primarily of sapling or larger size. Specific treatments are generally classified as cut stump, frill-girdle, and tree injection.

Cut-stump treatment consists of cutting trees to effect release of understory conifers. Stump spraying, a technique very similar to basal spraying, is then used to prevent regrowth through sprouting. Maximum effectiveness is obtained by application of chemicals immediately after cutting. Stump sprays, using chlorophenoxy herbicides. are also successful methods for site preparation and for use after clearance of trees on utility and roadside right-of-ways.

The frill-girdle treatment is one of the oldest silvicultural techniques utilized for control of large undesirable species or cull trees. This method employs the use of an axe to hack through the bark in single, overlapping or double cuts around the circumference for the tree. The resultant frill of axe cuts girdles the tree and prevents carbohydrate transport to the roots, causing their eventual starvation.

The degree of kill obtained by mechanical girdling alone is variable, and, even where complete girdles are made, trees may continue to live for three or more years. Frequently, callus tissue forms over the girdled area and provides a pathway for sufficient transport to sustain life in girdled trees. Herbicides applied in the cut surface immediately after girdling kill trees more rapidly. Sodium arsenite is one of the most effective herbicides for this purpose. However, because of its mammalian toxicity, it has largely been replaced by chlorophenoxy herbicides. The technique of placing ammonium sulfamate crystals in ace-cut notches at intervals around the base of standing trees is effective during the growing season.

The tree-injection treatment method is a modification of the frill-girdle technique. Tree injection is accomplished by driving a chisel blade or an automatic-metering hatchet through the bark into the xylem of the tree and releasing herbicide into the cut by a special device. Incisions are spaced 1 to 2 inches apart around the tree.

## Low Value Conifer Control

The control of low-value coniferous species is seldom a problem in established conifer stands. Control may be practical where it is desirable to improve stand quality by removing poorly formed and defective trees or less-valuable species. It is also applicable as a "cleaning" or "thinning" operation in dense, immature stands developing through natural regeneration or broadcast seeding. The objective of thinning is to concentrate the growth potential of the site on the future crop of desirable trees by providing adequate growing space and reducing competition for basic growth factors.

Because control of low-value conifers has been a minor problem, little research has been concentrated on it. Since the low-value trees are likely to be the same species as the crop trees, herbicide selectivity is ruled out, and selective management practices must be utilized. Most experience on individual-stem treatment has been derived from investigations into chemical peeling of conifers in thinning or harvest operations for the production of posts and poles.

Hand cutting, although not economical, is highly selective and has been used for conifer control in restricted areas under intensive culture. Most conifers do not produce sprouts from the root-collar zone; therefore, regrowth after cutting is no problem. Selectivity may be obtained with herbicides by cut-surface treatments frill, girdle, and tree injection. Basal-spray treatments are generally less effective than cut-surface treatments in conifer control. Basal, frill, or injection applications of herbicides frequently have the undesirable effect of killing untreated neighboring trees through root-graft translocations. Ponderosa pine is particularly susceptible to this hazard.

Thinning treatments can be used to achieve small group openings in the forest, in contrast to individual tree thinning. This technique utilizes nonselective soil-applied herbicides to kill all trees in a small localized area. Substituted urea herbicides, such as fenuron, show some promise for chemical-thinning techniques. The method has not been thoroughly tested and should be used with caution, since these soil sterilants are nonselective and may be taken up by trees outside the treated areas.

## Nurseries and Plantations

### Nurseries

Weed control in conifer nurseries often justifies greater expense than almost any other crop on the basis of crop value. The diversity of species among weeds and crops requires judging each situation separately.

Various combinations of hand weeding, cultivation, and chemicals are employed for weed control in nursery beds. Expensive hand weeding can serve as the primary method of control only where weed densities are low. As weed infestations increase, either cultivation or herbicidal weeding supplements hand weeding. Cultivation between nursery beds is increasing, but this method of weed control is not not suitable for nursery beds unless seeds are sown with drills. Where large weed populations are present, herbicidal weeding is usually favored, since it is less expensive, quicker, and does not require management of large weeding crews. Hand weeding, however, is still necessary in all nurseries, even where cultivation and herbicidal weeding are primary methods of control.

Chemical weed control in nursery beds is beneficial as a site preparation measure. Herbicides such as methyl bromide and amitrole-T are used in some nurseries to prepare seedbeds for sowing. Methyl bromide is usually applied as a soil fumigant in the fall for preplant weed control. Later, the beds are sown with a cover crop that is turned under in the spring, just before the beds are planted. In contrast, amitrol-T is applied in the spring at least two weeks before the beds are tilled and prepared for sowing.

### Field Plantings

The success of field plantings of tree species is dependent on the ability of planted stock to survive the first season and go on to dominate the associated vegetation that prevails under natural conditions. In areas where summer moisture is critical, herbaceous vegetation or weeds may so deplete the soil moisture or provide such strong competition that the plantings fail. Reduction of weed cover conserves moisture and favors maximum use of the soil by the planted stock. Removal of heavy herbaceous cover reduces, by a considerable degree, the temperatures in the vicinity of transpiring foliage of planted stock.

Reduction of transpirational stress resulting from increases in available soil moisture have been accomplished with applications of atrazine, 2,4-D and other herbicides at rates sufficient to provide 90 to 95 percent reduction of cover. This practice has been widely adopted in the Pacific Northwest, with excellent results. Conifer plantations have generally responded well to the use of atrazine, although it may result in minor discoloration of foliage tips, particularly on true firs, various pines, and Douglas-fir. Benefits derived from the treatment outweighed light damage to the true firs. Christmas tree growers, in particular, have found that herbicide treatments improve survival, growth rate, color, and form.

Herbicide applications by helicopter, airplane, and ground rigs are generally successful. Selectivity is good with treatments applied before or after planting. Spot treatment is often suggested for operators who have limited acreage and hand equipment.

## Christmas Trees

Christmas trees are either grown in plantations or selected and cultured in natural stands. They require far more intensive management than ordinary forest lands, since they are harvested while young. Weeds may reduce survival, stunt growth, result in poor foliage cover, and prolong rotations. In addition, the tree crop must meet certain uniform requirements and weeds can result in poorly shaped trees.

Many of the treatments developed for forest lands, including aerial spraying, may be used on Christmas tree plantations. However, more selective treatments are generally preferred, such as basal spraying, cut-surface treatments, and use of ground spray equipment, since these techniques minimize tree growth abnormalities. Weed control on Christmas tree plantations is practiced in preplant site preparation, at the time of planting, and in postplant operations.

Before planting, herbicides such as dalapon, amitrole, glyphosate, simazine, and atrazine are used to eliminate grass and herbaceous weed cover and are applied in strips or spots at a proper width for subsequent tree-planting and spacing. Weed control at planting time is also carried out to provide optimum control during the first growing season. Procedures have been developed in recent years for the simultaneous application of herbicides during machine planting. The method involves spraying a continuous strip 2 to 3 feet wide with a low-pressure sprayer attached to a tractor ahead of the tree planter or spreading granular herbicides with an applicator towed behind the planter.

After establishment, weed control may be accomplished by specially designed rotary mowers that travel between rows of trees. Mowing may be required two or three times a year depending on the weed species present and growing conditions. Mowing cannot eliminate weeds immediately adjacent to the tree, however, and many growers employ a combination of methods: herbicidal control in the vicinity of the trees and mowing between rows. Herbicides recommended for general weed control in established plantations include simazine, either in wettable powder or granular form, and a mixture of amitrole and simazine.

## Secondary Effects of Forest Weed Control

Secondary effects of weed control measures on a forest are those other than the benefits sought by the treatment. For instance, a weed control measure that facilitates or increases timber production will likely affect wildlife. Wildlife benefits would be a secondary effect.

The most obvious secondary effects of weed control measures in the forest upon multiple use are in relation to wildlife food and habitat and recreational and scenic values.

The killing of old cull trees in stand improvement operations has been criticized by wildlife scientists because these trees often serve as animal dens or perches. When cull trees are killed, they deteriorate rapidly and may fall within a few years. In locations where old trees are especially important to local wildlife, it has been recommended that at least one such tree per acre be left untreated.

When aerial applications to release pines first started in the South, there was great concern about the effect on wildlife, particularly squirrels, from treating large blocks of oak and hickory scrub. It was not uncommon to treat a thousand acres in one block. More recently, a checkerboard pattern of smaller areas, some only 50 acres in size, has been employed. These smaller areas have not noticeably disrupted the wildlife habitat. A survey showed that the plant species listed as most desirable by wildlife specialists were those that foresters reported were hardest to kill.

All manipulations of stand density and shrubby ground covers will affect one form or another of wildlife. Some treatments may reduce cover or food supplies; others may be beneficial, particularly when sapling or pole stands are opened up to favor understory browse plants. Stand improvement and release treatments, either mechanical or chemical, that do not result in killing the root may be followed by prolific stump or basal sprouting, offering increased browse for deer.

Weed-control measures for timber production may have adverse effects on aesthetic values. Any operation that results in extensive browning of summer foliage near highways, campgrounds, or other public-use areas is objectionable. Broadcast spraying of herbicides is especially offensive unless performed during periods of reduced activity. Other methods of accomplishing the objective should be employed wherever possible in areas exposed to public view. Where foliage browning cannot be avoided by cheap, practical means, forest administrators can forestall some public reaction by announcing the purpose of the treatment and providing assurance that the displeasing appearance will be temporary.

Brush control along forest roads generally consist of individual stem treatments that result in a minimum of browning. Where many sizable woody plants are involved, cutting and removal of the tops is often recommended, followed by treatment of the stumps with a herbicide. In parks and along trails, removal of plants such as poison ivy, poison oak, and poison sumac by herbicide sprays has made the woods more comfortable for many people.

Mechanical brush control often results in soil disturbance that may be aesthetically undesirable, increases erosion, reduces site productivity and adversely affects streams. On the other hand, clearing brushlands makes the areas more accessible, and new plants that occupy cleared sites may provide more and better forage.

Forestry weed control methods used should be chosen in accordance with primary lands use requirements and to the benefit of all who use the area.

## CHAPTER X

# WEED CONTROL ON RANGELAND

### Introduction

Weeds and brush are a problem on many forage lands. In areas where vegetation is disturbed or removed, remaining or newly introduced species tend to increase and can become dominant. Trends toward dominance by weeds can be halted or changed by judicious use of mechanical and chemical control methods, introduction of new forage plant species, fertilization and control of the kinds and numbers of grazing animals and their seasonal use.

Domestic livestock, game, rodents and other animals contribute to range weed problems by spreading seeds or vegetative propagules and creating opportunities for the establishment of weed seedlings. Grazing alters the botanical composition of range vegetation due to differences in palatability of plant species as forage and their ability to withstand grazing. Animals first graze the most palatable forage plants on easily accessible parts of the range or in patterns characteristic of the animal species. As plants are progressively weakened by close, frequent cropping, less palatable plants, some of which are considered to be weed species, grow unhindered.

Severe grazing may kill forage plants. Persistent heavy grazing increases the proportion of short grasses at the expense of more-productive taller grasses. The vigorous tall grasses offer greater resistance to invasion by range weeds such as spotted knapweed, white top, Canada thistle and others. Good grazing management usually results in more desirable species composition, vigorous individual forage plants and ample seed production. Usually, perennial grasses thrive under stocking rates that remove about 50 percent of the year's herbage. Range seeding and related cultural practices may also be used to directly increase forage stands.

Because of factors such as climate, native animal life, plant species and soil depletion or erosion, some ranges do not respond readily to improvement measures. Nevertheless, many forage lands can be made more productive by present techniques, which almost always include some form of brush and weed control.

## Brush Control

In Montana brush cover is either native vegetation that has invaded large areas of former grasslands converting them to brushlands, or climax shrubs types, such as big sagebrush.

### Management

Sound management principles are essential to the use of any control method on brush and noxious weed infested rangelands. Once established, noxious weeds and sagebrush cannot be eliminated by good grazing practices alone. Undesirable plant control must be combined with other practices favorable to forage production. Careful consideration should be given to selecting methods that are most effective for a particular range and its specific vegetation. A satisfactory management approach to one site may not work at all with another. Each method of control has advantages, and many have certain limitations, but the objective in all cases is to substitute forage species for unwanted vegetation.

Adverse environmental conditions in arid and semiarid rangelands make seeding difficult. Weed control is therefore of utmost importance when invasion is just beginning and grass has not yet been depleted. In brush infested areas that still have a good stand of grass, a herbicidal or mechanical method of control should be employed that will not destroy the grasses.

Some form of deferred or rotational grazing is particularly necessary to restore forage after control treatments on overgrazed sites near sources of water and salt. Alternate periods of grazing and nongrazing on range are the best means of improving forage stands to the point where establishment of weed seedlings is reduced. Intervals between grazing reduce the amount of grazing on more accessible sites and permit forage plants to regain vigor and set seed.

Benefits from control of noxious weeds, poisonous plants and brush are not confined to grass production. Such controls may increase the ease and reduce the cost of caring for livestock, increase livestock offspring, lead to a need for fewer breeding males, result in tamer livestock, reduce parasitic damage, improve the habitat for many wildlife species and result in more groundwater over a longer period.

Undesirable plant control methods vary greatly in cost and effectiveness and include chemical, mechanical and manual, as well as biological and selective grazing measures. Because potential income from grazing lands with a weed problem is low, costs and benefits of various alternative methods should be subjected to more rigid scrutiny than would be necessary for more valuable lands. Due to the large areas involved, eradication on rangelands is rarely an objective; emphasis is usually placed on control or regulation of a problem weed species. One of the major difficulties in achieving control is the efficient reproduction of many species.

## Chemical Control

Good weed control and striking improvements in the grazing capacity of rangeland may often be obtained most economically by low-rate and low-volume applications of foliar sprays. Economical control methods have been developed for numerous plant species, although much research still remains to be done.

Herbicides such as 2,4-D, 2,4,5-T, silvex and benzoic acids control a wide variety of species. Picloram also shows exceptional promise on many brush species. A combination of 2,4-D and 2,4,5-T sometimes is used to control mixed brush because of the differential susceptibility of species, although 2,4-D and 2,4,5-T do not act synergistically and their effects are not fully additive.

To be effective, foliar applications of systemic herbicides must be applied at the proper stage of growth. This must be determined experimentally for each weed species. Failure to carry out treatment at the proper growth stage often results in lack of successful control. Treating a weed species even one week too early, for example, drastically reduces the effectiveness of herbicides.

Brush is most susceptible after the flush of new leaf development has stopped and terminal growth has slowed, and before the production of thick leaf cuticle. This stage also coincides with the time that transport of photosynthate to the roots begins. Since herbicides are translocated coincidentally with the photosynthate, there is greater probability they will reach roots and kill the plant.

Plants are generally most sensitive to foliage sprays of growth-regulator herbicides under optimum growing conditions. In some dry years, herbicide treatments should not be made at all, since plants under moisture stress do not readily translocate herbicides.

Weed control on rangelands may not last indefinitely after treatment. Species may resprout from the base of the stem or roots after tops are killed or re-established from available seed sources.

Recovery over time depends on the plant species and environment. As a result, retreatment becomes necessary, and ranch managers should plan for a long-range follow-up control program on grazing units. To achieve adequate initial control of many plants, two or more herbicidal treatments may be necessary in consecutive or alternate years.

Soil applications of herbicides are another means of chemical brush control. Variability in seasonal susceptibility is not as great a problem with herbicides absorbed from the soil as with foliar applied treatments. Monuron, fenuron, picloram, dicamba and other herbicides are applied as granules in broadcast treatments or around the bases of individual plants. Applications should be made when there is a reasonable chance that rainfall will carry the herbicide into the soil. If herbicides are applied to soil when rainfall is light, losses of herbicide through photodecomposition and volatilization may be excessive.

Individual stem treatments of brush with herbicides are usually limited to situations where there are sparse stands of single-stem trees or small areas of rangeland. There are three categories of stem or basal treatments: basal stem, frill or tree injection and cut stump. Refer to Chapter IX for specific techniques.

## Mechanical and Manual Methods

The choice of whether to use manual methods, such as cutting or grubbing, or mechanical equipment to remove unwanted vegetation depends on the size of plants, whether the species have sprouting or nonsprouting characteristics, soil conditions and the type of terrain. Mechanical methods have been used for control of mixed stands of brush and species that occur in almost pure stands. Various techniques and types of equipment have been developed for different situations.

The best time for cutting or grubbing is during early invasion, before the grass stand becomes greatly reduced. Hand grubbing or cutting sparse stands of small shrubs (up to 36 inches in canopy diameter) is an economical control method. With sprouting species, the root must be severed below the budding zone. With large trees and mulitiple-stemmed plants, the cost is usually prohibitive. After cutting, sprouting species may be treated with herbicides to prevent sprouting.

Mechanical methods of rangeland brush control include cabling or chaining, bulldozing, root-plowing and discing.

Cabling or chaining is the process of uprooting trees or shrubs by means of a 300 to 500 foot length of anchor chain or heavy cable looped between two large tractors traveling in a parallel direction. This method has been most effective in controlling even aged, mature, nonsprouting species such as one-seed juniper and Utah juniper. It is less successful against sprouting species.

Chaining will not severely damage small trees or shrubs that easily bend, and medium-sized plants may be only partially uprooted. Follow-up work by bulldozing or hand grubbing is required in stands that contain a large number of small or medium-sized trees.

Bulldozing is effective against medium-sized trees of some basal-sprouting species and sparse stands of any species, since it pushes or pulls the plants out of the soil. Small trees and shrubs are often overlooked and may not be removed by this method. Large trees are difficult to uproot. One of the problems with bulldozing is that soil is torn up and large pits are left.

Root-plowing with a track-type tractor and horizontal blade cuts off brush below the ground surface. Fins are welded to the top of the back of the blade to push roots out of the ground and reduced the possibility of their rerooting. Root-plowing generally kills most of the brush and almost all other vegetation in an area. It is essential that the blade strike below the budding zone of plants.

Root-plowing is limited to deep soils that are fairly free of rocks and obstructions. Areas that are root-plowed must be seeded, so the operation should only be carried out in areas favorable to the establishment of forage species by seeding. Because a high percentage of control is achieved, root-plowing is effective if there is no seed source of the woody plants in the soil or in nearby areas.

Discing for vegetation control is carried out with a large disc plow, or tandem disk. This method is limited to small, shallow-rooted plants such as sagebrush. Soils must be plowable and should contain few desirable grasses, since discing destroys most of the grass that is present. Disced areas may then be seeded with desirable grasses. Limitations that apply to root-plowing are generally the same for discing.

Another brush-control method, the oldest in use, is prescribed burning. Results of burning vary greatly and depend on the susceptibility of desirable and undesirable species to fire and the amount of fuel accumulation that may be obtained from associated forage species. Time of year and moisture relationships are also important. Because burning involves such variables and may prove hazardous to other resources, extreme care is needed when fire is used. Used improperly fire can reduce range condition.

If burning is employed, consideration must be given to the direct effects of fire on forage species and the tendency for livestock and other animals to concentrate on recently burned areas. Forage species vary in their susceptibility to fire, and the season of greatest susceptibility for the undesirable plants may coincide with that of the forage species. Heavy grazing, coupled with frequent burning, will eliminate the better forage plants.

Several kinds of undesirable range shrubs are ideally controlled by burning at the proper season if moisture conditions are satisfactory and adequate precautions are observed. One example is big sagebrush, which does not sprout stongly after burning. Fire gives a very limited degree of control, however, to a number of shrubs and trees such as rubber rabbit brush since it resprouts if burned. After burning, seeding is generally carried out in the ashes. Spraying of sprouts and seedling brush and weeds should be performed the year after burning. Spraying of older brush is less effective.

Burning is no cure-all for range brush problems, nor is it necessarily cheaper than other methods. Provisions must be made to insure that fires do not get out of control. This requires adequate preparation, trained manpower, fire-control equipment, prearranged firebreaks, and judgment as to when burning should be undertaken and when and where it should be stopped. The use of desiccating herbicides to permit more latitude in selecting the time and place of burning is under investigation but is not yet a widely recommended practice. Cost of burning includes not only the cost of fire lines and other safety precautions, but also the loss of one or more forage crops that are permitted to accumulate as fuel. Wherever burning can be fitted properly into a comprehensive, long-range vegetation management program, however, it does control a number of woody plant species.

## Biological and Selective Grazing Methods

Biological control of brush may be achieved by the use of insects or diseases as enemy agents of plant species or through selective grazing. Discussion will be confined to selective grazing.

Selective grazing by sheep or goats is useful in controlling species of plants in small areas. The animals select the more palatable plants or portions of plants and are particularly effective in controlling seedlings and young sprouts. The tops of larger trees and shrubs should be removed before selective grazing is begun. Close and continuous grazing is essential to suppress and kill brush.

Careful management is necessary with selective grazing, but brush stands can be greatly reduced in three to five years if newly controlled areas are stocked with one to five sheep or goats per acre for the first two years and with lighter numbers thereafter. Overgrazing, especially at the wrong times of year, can be more detrimental to forage species than to the brush species being controlled. Expenses for the necessary fences, water, death losses and management of animals can be high.

## Herbaceous Weed Control

Herbaceous weeds are found on all rangelands, and their harmful effects vary with range conditions. Good ranges usually have fewer herbaceous weeds; such weeds are abundant on poor ranges. Loss of forage from herbaceous weeds on rangelands is often spectacularly apparent as is the case with leafy spurge and spotted knapweed.

### Grasses

Grasses are an important group of herbaceous weeds and they dominant vast areas of rangeland throughout the world. Many grass weeds spread readily and displace forage plants. Annual grasses such as downy brome and medusahead are examples of serious grass weeds in rangeland. Due to low palatibility of these weeds, they accumulate on rangeland and create a fire hazard. Dead litter also builds up and inhibits early growth of seedlings of planted species.

Control of most grassy weeds is essentially a matter of sustained suppression by perennial forage grasses rather than total elimination. Vigorously growing dense stands of perennial forage grasses can maintain suppression of weedy annual grasses.

The similarity in physiological and environmental requirements of seedlings of annual and perennial grasses makes selective herbicide control almost impossible. Siduron, which selectively controls seedlings of crabgrass, foxtail, downy brome, medusahead, and many other weeds without injuring seedlings of bluegrass, crested wheatgrass, and fescue, has some potential for control in rangeland. One limiting factor for siduron is that moisture must be available soon after treatment for effective action to take place. It is most important to note that siduron only shows promise and as of yet is not registered for use on rangelands.

Herbicides active in soil, such as atrazine, effectively control annual grasses but are also toxic to perennial grasses. To achieve selectivity between the weed and seeded species, methods must be employed that are based on either timing or placement or a combination of both. A chemical fallow technique in which atrazine is applied in the fall of one year and perennial grasses are seeded the next has proved effective. Atrazine is nearly always dissipated from the soil during the intervening year. Weed control during that year eliminates seed production and conserves soil moisture and nitrogen. The technique reduces annual grasses markedly during the seeding year, but sometimes increases broadleaved weeds. Under such conditions, good stands of crested and intermediate wheatgrass have been obtained by planting the seed in furrows and spraying broadleaved weeds with 2,4-D the following spring.

## Broadleaved Weeds

Broadleaved herbaceous weeds are serious problems in rangelands, since many of them are unpalatable, poisonous or cause mechanical damage because of spines and thorns. Because livestock avoid such weeds unless other forage is lacking, broadleaved herbaceous species tend to increase on improperly grazed ranges. Furthermore, they compete directly with desirable forage species for moisture and nutrients, decrease the amount of forage produced, and inhibit establishment of forage seedlings.

Other serious broadleaved weed problems occur when noxious weeds become established on rangeland and then invade nearby agricultural crop land. Many of these weeds must be controlled under state or local law.

Control of broadleaved herbaceous weeds is complicated by the fact that individual species often occur in scattered stands, frequently on terrain not easily accessible for direct control measures. Some species, such as the low larkspurs, mulesears and lupines, occur in stands of sufficient density and area to justify broadleaf applications of herbicides.

Many species, notably the poisonous larkspurs (Delphinium spp.) and deathcamas (Zigadenus spp.), become more resistant to phenoxy herbicides at later growth stages. Time of treatment is therefore critical. In addition, species such as the tall larkspurs begin growing as snowbanks recede. This results in many growth stages among closely associated plants of the same species. Under these conditions, plants may range from susceptible to resistant and therefore retreatment becomes necessary and eradication is costly.

The extensive root systems of some perennial herbaceous weeds, exemplified by Canada thistle, leafy spurge, whitetop and whorled milkweed, and the variable effectiveness of phenoxy herbicides on such plants makes repeated treatments necessary. Despite the need for repeated annual treatments with phenoxy herbicides, they are in general use in combination with improved grazing management, cultivation and reseeding. Reasonable control may be achieved in this way, but eradication is seldom achieved on grazing land.

## Poisonous Plants

More than half of the perennial broadleaved herbaceous plants recognized as weeds on rangelands are poisonous. Some of these are introduced species, others are native plants. Few of the poisonous weeds are abundant, even locally, on good range. Examples of locally abundant poisonous species in climax vegetation are tall larkspur, deathcamas, locoweed and crazy weed. Many poisonous plants increase in density on misused rangeland because they are not grazed when palatable forage plants are available. However, there are exceptions such as tall larkspur and locoweed (*Astragalus* spp.) that may be habit-forming to livestock.

Poisonous plants are found on nearly all rangelands in the western United States. Whether they present a problem depends on a number of factors. Toxicity of poisonous plants varies with species and their stage of growth. Sneezeweed (*Helenium* spp.) is mildly poisonous; animals may become ill from them but seldom die if they are removed from an infested area when symptoms first appear. Timber mildvetch is so toxic that once cattle exhibit symptoms they seldom recover. Tall larkspur is most toxic during early growth stages. Halogeton becomes more toxic with age.

Sparse infestations of poisonous plants are seldom troublesome. Heavy stands of even mildly toxic plants may constitute a serious hazard to livestock. Even small areas of dense infestations of highly toxic species may remove large areas of grazing lands from profitable production.

The life cycle of a poisonous plant may determine whether and when it is a range problem. Low larkspur and deathcamas are problems on ranges grazed early in the year because they are among the earliest green plants available to livestock. On similar ranges grazed later in the season after forage plants are large enough, the animals seldom eat these poisonous species. Still later in the season, both plants complete their life cycles and disappear from the range. Tall larkspurs, however, may reach maximum toxicity during the grazing season.

Poisonous plants are not equally poisonous to all classes of livestock. Tall larkspur and timber milkvetch are far more toxic to cattle than to sheep. Only a few cattle losses are definitely known to be caused by halogeton poisoning, but thousands of sheep losses can be attributed to the plant.

Poisoning is one of the most persistent problems confronting the livestock producer and economic losses from it are heavy. Estimates indicate 3 to 5 percent of the livestock deaths on larkspur infested rangelands can be attributed to the plant. In some years, deaths on such ranges are higher than 15 percent.

Losses from poisoning may be reduced by identifying the weed hazard and keeping livestock out of the area; providing an abundance of forage through improved grazing management, especially in areas where poisonous plants are unpalatable; and controlling or eradicating the infestation. Usually, control of the weeds by some means is the most desirable approach.

Where good range management or other biological control practices do not reduce poisonous weeds to nonhazardous levels, herbicidal treatment may be necessary. Properly timed applications of certain herbicides control many poisonous weeds. Repeated annual treatments are required for most perennial species and for annuals and biennials if there is a residual seed supply. The benzoic acids and picloram show special promise against some poisonous weed species.

On sites where herbicides are used for control, judicious grazing management is necessary to increase desirable vegetation, both in vigor and number of plants, thus reducing the possibility of reinfestation. If an area does not contain sufficient palatable species for natural revegetation it should be seeded, if possible. Proper herbicidal treatments after seeding will reduce weed competition and increase the probability of successful control even on marginal sites. This fact has been demonstrated numerous times in salt-shrub desert vegetation when halogeton and Russian thistle were controlled in new seedings of crested wheatgrass.

The early detection of new weed species and prompt application of measures to prevent their establishment and spread are important to the maintenance of our western ranges.

Among introduced species of biennial and perennial broadleaved herbaceous weeds that are relatively limited in their infestation are Dalmatian toadflax, diffuse knapweed, spotted knapweed, leafy spurge and rush skeletonwood. These species are still confined to only portions of their ecological range, although they are spreading rapidly on foothill and mountain ranges. While eradication of any of these species is probably not feasible, vigorous efforts should be made to contain them in the present areas of infestation.

# CHAPTER XI

# WEED CONTROL ON RIGHT-OF-WAYS

## Introduction

Right-of-ways are areas involved in common transport. They are necessary for the proper functioning and safety of transportation facilities and installations. They include: 1) highways and roads; 2) public airports; 3) railroads; 4) electric utilities (including transformer and sub-stations); 5) pipelines; 6) surface drainage ways; 7) irrigation water ways; and 8) bicycle, bridle, snowmobile and other public paths or trails. Right-of-ways encompass every soil type, climate, vegetation complex, land use area, and type of topography. Control of vegetation must be planned around the specific area to be treated.

Any vegetation along a right-of-way may need to be controlled if it is: 1) a safety hazard; 2) a nuisance; 3) unnecessarily impedes operational and maintenance activities; 4) causes injury to man or animal; 5) has been legally declared "noxious"; 6) has a repressive effect on desired right-of-way vegetation; 7) causes damage to structures such as road surfaces and rail ballast; or 8) detrimental if it persists and spreads to adjacent crops. A planned vegetation management program with stated goals and objectives provides a comprehensive, rational approach for control and management of the right-of-way environment.

## Selective Vegetation Management

Vegetation management is the selective stimulation of competition between desirable, less desirable, and undesirable vegetation. Reseeding operations, new species introduction, selective spraying, cutting frequencies and fertilization are all practices used to change vegetation composition.

The vegetation that occupies right-of-ways should be predominantly grasses, grass-like plants, legumes, forbs (including wildflowers), or shrubs. Right-of-ways include grasslands (native or introduced), savannas, shrublands, deserts, tundras, forests, crop lands, alpine communities, coastal marshes, wet meadows and some non-productive areas such as barren rock. Also included is the transition area where forest and open areas meet.

In the development of a new right-of-way it is possible to control location and design to help certain effective vegetation control. Costs and difficulties in future management and control are directly affected by this preplanning. Corridor and site selection offer an opportunity to place the right-of-way in a favorable relationship to topography, drainage ways, soils, other natural features and present or anticipated man-made features.

Existing trees, shrubs and turf should be saved whenever possible. Once indigenous vegetation is removed, it is rarely replaced with the same kinds of plants. Disturbance of the site provides a different kind of seedbed and growing conditions for seedlings. Whenever possible it is a good idea to encourage regeneration of natural vegetation.

New right-of-ways should be tilled, fertilized, seeded and mulched. Seeding mixtures that best suit local conditions must be selected. Rapid establishment of vegetation prevents invasion by weed species as well as reducing loss due to erosion. Seeding mixtures should vary between locations depending on soil type, local weather conditions and the level of maintenance required.

Whenever possible, do not disturb existing drainage. Surface drainage should be well planned and hydraulically adequate. Naturally shaped channels of nonerosive soils, well-stabilized with vegetation should be developed.

Some annual weeds may be partially controlled by mowing to prevent seed production. Mowing operations should be planned and monitored for effective results. Increased frequency of grass mowing leads to fine-textured grasses. Decreased mowing results in tall, coarse-textured grasses and other plants. Mowing frequency for brush control varies with species and climate. Timing is important for safety, appearance, weed control, and to cause vegetative changes. Reel mowers are used for a neat appearance. Heavy rotary mowers are used for brush control.

Selective herbicides are used to control specific undesirable plants. Their removal improves the right-of-way environment and benefits the overall well-being of the transport facility, its uses and adjacent property owners. To be successful, the weed must be correctly identified and the right chemical applied at the right time. Whenever possible use a selective spot spraying treatment rather than a broadcast blanket spray program. This reduces costs, damage to desirable species and helps reduce public concerns regarding misuse of herbicides.

## Nonselective Vegetation Control

Nonselective vegetation control may be necessary around sub-stations, pole yards, pumping stations, storage areas, guardrails, signposts, runway lights, parking areas, railroad yards, in railroad ballast, in pavement cracks, and on highway shoulders. Vegetation in these areas could be a fire or safety hazard, restrict visibility, damage structures, provide a breeding area for rodents and other pests as well as reduce facility security.

Nonselective herbicides are chemicals which kill all vegetation and may leave the soil nonproductive (barren) for a year or more, depending on the chemical and the rate used. The material in most cases must have the ability to knock down existing vegetation and also prevent or inhibit regrowth and germination for a time.

The material or materials selected should not move laterally in the soil and the application should be in an even pattern at prescribed rates to prevent surface movement, damage to abutting areas, plant life, or soil erosion. Generally such materials should not be applied to slopes greater than 6:1, horizontal to vertical, without a cap or other means of protection or containment.

Water movement over areas treated with a soil residual herbicide must be prevented, or contained on site, to avoid damage to other areas and soil erosion. The chemical (depending on what is used) may be capped with an asphalt, or mixed in with a cut-asphalt and sprayed over the surface. The barren surface may be protected from erosion with crushed stone. Railbed ballast and pavement cracks generally do not present chemical movement problems. A planned retreatment program is generally required.

Kill of established perennial vegetation by soil residual chemicals is slow and may impair the effectiveness of the treatment. To improve effectiveness, contact or translocated herbicides may be combined with soil residual herbicides. Vegetation on these sites may be mowed closely and removed before treating the area. Vegetation may be removed from around guardrail posts with a shovel. Blading can also be used.

In some situations where a vegetation cover must be maintained and mowing is not practical, growth retardants may be used. They are safer from a movement and erosion prevention standpoint, but may result in an increase in undesirable vegetation.

# SECTION III

# FOREST PATHOLOGY

## CHAPTER XII

## TREE DISEASES

### Introduction

Tree disease is defined as an injurious condition, usually expressed by abnormal growth or development of a tree, and caused by something other than fire or insects. This includes disorders that kill trees, reduce growth, lower quality, or predispose trees to attack by other agents.

Diseases are identified by symptoms or signs. Symptoms are expressed by abnormal growth or development of the tree such as dead or dying plant parts. Signs are evidence of the causal agent such as conks or other types of external fungus growth.

Noninfectious diseases are caused by nonliving agents such as unfavorable climate, a deficiency or excess of nutrients or moisture, or air pollution.

Infectious diseases are caused by living agents such as fungi, bacteria, and higher plants.

### Noninfectious Diseases

Noninfectious diseases do not spread from tree to tree, but do affect trees growing in the same environment. Different species and trees of different ages and vigor vary in their susceptibility to damage. Factors causing these disorders may operate for only a brief period (frost), for most of the growing season (prolonged summer drought), or cumulative for a period of years (air pollution).

BURLS, GALLS, AND TUMOR-LIKE GROWTHS are abnormal swellings on stems or branches that occur on most tree species. They vary in size and may reach several feet in diameter on large trees. The tree produces a large excess in number or size of cells in response to some form of disturbance to the cambium. These disorders are seldom of economic importance.

POLE BLIGHT of western white pine causes a reduction in leader and branch growth. Old needles drop prematurely. Younger needles are few, clustered near the ends of the twigs, and are short and yellow. Crown symptoms spread downward and inward until the entire crown becomes relatively open. A distinctive symptom is the presence of flat or depressed areas in the bark of stems showing excessive resin flow. Pole blight is induced by extended periods of unusually dry weather on dry sites with low soil fertility.

RED BELT OR WINTER DAMAGE occurs on all conifers if conditions are right. Foliage may be killed if exposed to warm drying winds when the ground is frozen because the trees are unable to replace the water lost through transpiration. In mountainous country, injury may be confined to an altitudinal zone corresponding to the pathway of drying winds or to the transition zone between warm and cold air in a temperature inversion; hence the name red belt. Height and diameter growth are retarded, damaged trees may be predisposed to attack by other agents, and some trees may be killed outright.

AIR POLLUTION INJURY to foliage occurs when toxic gases are emmitted from smelters, reduction plants, or coal-burning industries and power plants. Toxic gases usually involved are sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), fluorides (F-), and heavy metals. The foliage usually absorbs the gases for a prolonged period before the injury becomes visible. Symptoms and severity of damage vary between tree species, concentration and type of gas, duration of exposure, and distance from the source. Discoloration of conifer needles starts at the tips, while broadleaved foliage is affected first in the tissues between the veins, giving the leaf a mottled appearance. Foliage, buds, branches and entire trees may be killed; damage sometimes occurs over an extensive area.

## Infectious Diseases

Infectious diseases spread from tree to tree, or in the case of rusts, from tree to alternate host to tree. Many infectious diseases have a narrow host range; in some cases they occur only on a single host. Severity depends on susceptibility of the tree, virulence of the casual agent, and environmental and other factors that influence host resistance and growth of the casual agent. Disease may vary in importance between tree species in one area or in the same tree species in adjacent areas. Most infectious diseases are caused by fungi. Microscopic examination is required to identify many casual agents, but most may be recognized by their gross appearance - signs and symptoms.

Any part of the tree may be attacked. Disease classification is based on casual organism (dwarf mistletoe, rust fungi), or part of tree affected (root, stem and branch, or foliage).

In order to develop adequate management prescriptions for an infectious disease, we need: 1) a proper diagnosis, 2) how the disease is spread, 3) the host range, and 4) what stand conditions can be regulated (age, stocking density, and species composition).

## Dwarf Mistletoes

Dwarf mistletoes are parasitic seed plants dependent upon conifer hosts for growth and survival. Their modified root system is embedded in bark and wood tissues. Their aerial shoots are basically reproductive structures, but they do contain chlorophyll and manufacture some of their carbohydrates. Most of their carbohydrates and all of their water and minerals come directly from the host, resulting in some significant effects on the host:

1. Mistletoes reduce both height and diameter growth rates.
2. Mistletoes weaken trees and make them more susceptible to attack by insects.
3. Mistletoes kill trees directly.
4. Heavily infected trees produce fewer seeds and seeds of lower viability than healthy trees.
5. Host wood in bole infections is altered and is not as strong as healthy wood.
6. Mistletoes may influence forest succession and changes in species composition.
7. Dead trees, lower limbs, and heavy brooms make trees more flammable and increase fire danger.

The mistletoes have an explosive seed dispersal mechanism; the single seed is shot from the fruit at 80 to 90 feet per second (60 mph). Average horizontal distance of seed flight is about 20 feet; 90 percent of the seed falls within 30 feet. Seeds are sticky and usually adhere to whatever they hit. Rain makes the sticky coating slick, and if the seed slides to within a half centimeter of the twig, it will germinate. Shoots emerge from the bark in 2 to 3 years and produce seed in another 2 to 3 years. Individual shoots live 2 to 5 years, but the internal system lives as long as the host tissue.

There are four species of dwarf mistletoe infecting 11 native and four introduced tree species in Montana. The three major mistletoe species are:

1. Arceuthobium douglasii on Douglas-fir. Occurs throughout the range of Douglas-fir west of a north-south line roughly 25 to 30 miles east of Missoula.

2. A. americanum on lodgepole pine. Occurs throughout the range of lodgepole pine. Ponderosa pine is secondary host in some areas.

3. A. laricis on western larch. Occurs throughout the range of western larch. Lodgepole pine, subalpine fir, and mountain hemlock are secondary hosts.

4. A. cyanocarpum is a minor species that occurs on limber pine sporadically throughout the tree's range.

Features that make the dwarf mistletoe ideal an candidate for cultural management are:

1. They are obligate parasites; that is, they need a living host to survive. Once an infected tree or branch is cut, mistletoe dies.

2. They are generally host specific. Favoring a nonhost species during cutting reduces damage.

3. Infection from seed germination to seed production requires 4 to 6 years. This long life cycle means population buildup in trees is relatively slow.

4. They spread slowly through stands. Seed flight is limited to no more than 100 feet from a tall isolated trees. In even-aged stands, seed flight is even more limited, and lateral spread through the stand is only 1 to 2 feet per year.

5. Mistletoe infected trees and stands are easy to detect because signs and symptoms, that is, plants, swelling, and brooms, are readily visible.

## Management Suggestions to Reduce Mistletoe Impact

Losses can be reduced in managed stands through silvicultural treatment. Options include:

1. Regenerating the infected stand using treatments which eliminate the pathogen. Clearcuts are best, but seed tree and shelterwood cuts are suitable if the overwood is removed promptly after regeneration is established.

2. Removing infected overstory trees and thinning/sanitation of the understory. Lightly infected trees are suitable crop trees if they will otherwise release.

3. Changing stand composition to nonsusceptible species.

4. Removing infected residuals from logged or burned stands.

## Stem Rusts

The tree rusts are obligate parasites and require living hosts for survival. With few exceptions, they require both a primary and an alternate host plant to complete their life cycle. They are host-specific or are capable of attacking only a narrow range of plants. They produce as many as five different spore stages.

Stem rust infect the primary host trees through needles, grow into the branch and eventually into the main stem. Stems and branches may be girdled by the fungus and result in death of the tree above the point of girdling. The infection may also cause galls or resin-soaked cankers. Blisters containing yellow spore masses break through the bark of the infected area and release spores that infect the alternate host. Other spores are produced on the alternate host that can only reinfect the alternate host and intensify the disease. Later, still other spores are produced on the alternate host that can only infect the primary host and complete the life cycle.

### Native Rusts

STALACTIFORM RUST, caused by *Peridermium stalactiforme*, causes elongate cankers on lodgepole pine. Several herbaceous plants, including Indian paint brush, are alternate hosts for the fungus. Infection of needles takes place in late spring. The fungus develops in the needle tissue and spreads to the twigs and branches and eventually into the main stem. The cankers are many times longer than they are wide. Cankers are covered by a heavy resin flow. Branch infections cause flagging; main stem infections may cause top dieback or tree death. Spores produced on the cankers infect the alternate host to complete the life cycle. The rust is most damaging in seedling and sapling stands. Damage in older stands is usually cull without mortality. Rodent chewing of the bark and cambium near the canker edges is usually evident.

No practical controls are available, but infected trees should be removed during stand improvement or thinning operations.

COMANDRA BLISTER RUST, caused by *Cronartium comandrae*, causes cankers on lodgepole and ponderosa pine. Bastard toadflax is the alternate host for the fungus. The life cycle of this rust is quite similar to that of stalactiform rust. The fungus infects needle-bearing twigs of pine in summer or early fall and spreads to the woody tissue of twigs and stems. The fungus will eventually girdle the branch or stem and kill the parts distal to the canker. The pycnidial stage (sticky reddish-orange drops) appears on the bark 2 to 3 years after infection. In the spring or early summer of the following year, the aecial stage (orange blisters) appears. These blisters rupture and the spores are wind disseminated to toadflax to complete the cycle. Spindle-shaped cankers, branch flagging, and top dieback or tree killing are associated with the disease. The disease is more common in southern Montana than in northern Montana, and appears to be more common on lodgepole pine that on ponderosa pine.

No practical controls are available, but infected trees should be removed during stand improvement or thinning operations.

WESTERN GALL RUST, caused by *Endocronartium harknessii*, is a nonalternating rust apparently confined to lodgepole and ponderosa pine. Galls (globose-shaped swellings) produced on branches and twigs cause death of individual branches. Galls on main stems cause "hip" cankers, which affect form, lumber content, and growth rate, and may kill individual trees. The rust infects pine of all ages and occasionally causes severe damage in forest tree nurseries.

Removal of infected trees during thinning operations and intermediate cuts is the only practical way to reduce damage. In nurseries, seedlings with galls should be destroyed. Detection of seedling galls may be difficult, but there will usually be a slight swelling on the main stem. All infected pines in windbreaks, shelterbelts, ornamental plantings, or forest stands within 300 yards of nursery beds should be removed to prevent seedling infection.

## An Introduced Rust

WHITE PINE BLISTER RUST, caused by *Cronartium ribicola*, alternates between five-needled pines and *Ribes* spp. The disease cannot spread from pine to pine as does the western gall rust, but it is transmitted to pine by spores (basidiospores) produced on *Ribes* leaves. Pines are infected through the needles during late summer and fall. After about 3 years, spindle-shaped branch or stem cankers develop. The aecial or blister stage is produced on infected, swollen branches. After blisters break, aeciospores are disseminated by wind and infect *Ribes* plants.

White pine blister rust is the most common and damaging disease of five-needle pines in Montana. Blister rust is fatal to seedling, sapling and pole size trees; pole size trees and larger trees are not killed as quickly as smaller ones and usually attain merchantable size. Infections on small trees tend to be nearer the stem so the stem is invaded sooner. The stem is also smaller in diameter, thus more rapidly girdled.

Control efforts for many years included attempts to eradicate *Ribes* by digging or pulling the bushes by hand or spraying with herbicides. This proved difficult and ineffective, and attempts were abandoned in 1966. Application of antibiotics for direct control of the fungus on infected trees was also ineffective. For 10 years (1964-1974), no white pine plantations were established; silviculture was aimed at converting white pine stands to other species.

Current management strategies include integration of genetic resistance with cultural treatments.

*Genetic Resistance* - The White Pine Tree Improvement Program began in 1950 with a primary objective of developing rust resistant white pine. The program was later expanded to include breeding for growth and form as well. A limited amount of seed with rust resistance is now available and more will be available in the future. Only a portion of the seeds in any seed lot is resistant, so white pine and at least one other tree species is planted to achieve a mixed-species plantation.

*Cultural Treatments* - Although blister rust is much more damaging than our native rusts, it has not been as devasting as formerly feared. Uninfected trees which escaped infection or are resistant are common in many stands. Not all infected trees are lethally infected and many live to merchantable size. This means white pine can be maintained as a component of many stands. When thinning, leave trees that may be expected to live to merchantability; and when marking for a shelterwood or seed tree cut, mark trees that are likely to produce progeny with some resistance.

## Nonrust Cankers

Some fungi invade stems and branches and cause localized infections in the bark and underlying woody tissues and are referred to as cankers. A canker is defined as a sunken dead area. Cankers on the main stem below the crown may kill the tree by girdling; those on branches may cause only flagging.

Some canker diseases result in severe damage, but most of those found in Montana cause only minor damage. Most of the casual fungi are weak parasites; they usually attack trees weakened or damaged by some other agent. Common canker diseases in Montana include the following:

*Phomopsis* on Douglas-fir. Annual canker, sometimes causing terminal dieback.

*Cytospora* on quaking aspen, maple, cottonwood, and other deciduous trees, usually causing dieback above the canker. *Cytospora* on grand fir (true fir) causes branch tip dieback and occasional death of seedlings.

*Atropellis piniphila* on lodgepole pine. Perennial canker causing a distortion in growth and a blue-black stain of the sapwood and heartwood. Damage may be severe in dense stands, particularly those growing on dry sites.

No practical controls are available, but infected trees should be removed during stand improvement or thinning operations.

## Nonrust Foliage Diseases

Most fungi causing foliage diseases are confined to the needles, a few attack buds, and some also invade young twigs. Foliage diseases are generally more severe on seedlings, samplings and small poles than on larger trees. Most of the fungi affect either foliage of the current season or older foliage, rarely both; and it is unusual for all the foliage in either category to be involved. The fungi vary in virulence from year to year according to climatic conditions; heavy infection over a period of years is exceptional. Some trees in a stand are severely infected, but others escape with little or no infection, apparently because of individual resistance. Foliage diseases rarely cause mortality, but they do cause a reduction in growth.

Some of the more common nonrust foliage diseases in Montana are:

Rhabdocline pseudotsugae on Douglas-fir. This is probably the most damaging needle disease in Montana because of the Christmas tree industry. In the spring, the disease is characterized by red-brown needle spots and long brown cushion-like fruiting bodies on either side of the midrib on the underside of infected needles. During the summer, all the needles are cast and the only field symptom is the absence of one year's needles.

No direct control methods are available. There are strong indications that resistance to the disease is genetically related. If this is the case, seed from resistant trees would alleviate the problem in the Christmas tree industry.

Lophodermella concolor on lodgepole pine. This is the most damaging needle cast of lodgepole pine because it occurs frequently, is widespread, and causes defoliation and growth loss. The reddish diseased needles are easily confused with winter damage; but the fungus fruiting bodies mature and can be used to identify the pathogen. Direct control is not practical. Tolerant individuals should be favored during thinning because of the tree-to-tree variation in susceptiblility to the disease. Mixed species and vigorous stands may help reduce damage.

Hypodermella laricis on western larch. Infected needles are retained on the spur shoots for at least a year after healthy foliage has been shed. From a distance, heavily infected trees can be mistaken for defoliation caused by the larch casebearer.

Meria laricis on western larch. From a distance, heavily infected trees appear similar to H. laricis and casebearer defoliation.

No direct control methods are available for either of the larch needle diseases.

Elytroderma deformans on ponderosa and lodgepole pines. The fungus infects and kills needles, as does other needle diseases. In addition, E. deformans invades twigs and branches, causing stunting and reddening of needles, upward curving of branches, defoliation and witches' brooms. Brown dead lesions develop in the inner bark of twigs and branches. Thin black lines of fruiting bodies are produced on dead and dying needles of the previous year's growth. Infection is usually heaviest on pole and large sapling understories and in dense stands. Most infection occurs at edges of meadows, in wide draws and on gentle slopes where cool moist air drainage is common. Direct killing is rare, but infected trees are more susceptible to bark beetles and root diseases.

Minimize damage in young stands by maintaining good spacing. Select uninfected or only lightly infected trees as crop trees. Accelerate logging in heavily infected mature stands to salvage valuable timber and prevent losses from secondary causes. Remove all trees with more than a fourth of their twigs flagged or killed.

## Rust Diseases of Conifer Foliage

Conifers are attacked by several different foliage rusts. These diseases are capable of killing seedlings and small trees and of reducing the growth and vigor of mature trees. Yellow or occasionally white pustules occur on the surface of the needles. Severely infected needles may appear uniformly yellow. Some typical foliage rusts in Montana are:

*Melampsora medusae* on current year's needles of Douglas-fir. Severity depends on the climate and the presence of aspen, the alternate host.

*Chrysomyxa ledicola* may cause heavy defoliation of spruce in and near swamps and bogs where the alternate host, Labrador tea, is plentiful.

*Pucciniastrum epilobii* causes yellow needle rust of the current year's needles of true firs, especially subalpine fir in logged and burned areas where the alternate host, fireweed, abounds.

Direct control methods for needle rusts are not available. Maintenance of mixed species may help reduce the damage that occurs during occasional severe outbreaks.

*Fir broom rust*, caused by *Melampsorella caryophyllacearum*. Alternating between the true firs and chickweed. Forms yellow witches' brooms in tree crowns.

*Spruce broom rust*, caused by *Chrysomyxa arctostaphyli*. Alternating between Engelman spruce and bearberry (kinnikinnick). Forms yellow witches' broom in tree crown.

The life cycle of these two fungi are similar. Fungal spores from the alternate hosts infect young needles of fir and spruce. The fungus spreads into the woody tissue of branches and the main stem where yellow witches' brooms form. The color of the brooms is caused by yellow-orange fungal pustules produced on infected needles. Spores from these pustules complete the life cycle by infecting the alternate hosts. Needles are dwarfed; spindle-shaped swellings develop on the branches and trunks at infection sites. Unlike brooms caused by other fungi and dwarf mistletoes, rust brooms bear yellow needles which die and usually drop in the fall, and the broom appears dead during the winter. Principal damage is growth loss and tree mortality; the amount of damage depends upon the number and size of brooms and their position within the crown. Brooms may provide entry courts for decay fungi and cull may be significant.

Control of broom rusts is limited to silvicultural treatments of infected stands. Diseased trees can be eliminated through selective thinnings and infected branches can be pruned from high-value trees.

## Stem Decays

Stem and butt decay fungi enter living trees through trunk wounds, dead twigs, broken branches and tops, or roots. The fungi develop within the tree, usually with no visible signs of defect. They may eventually produce conks which produce spores capable of spreading the decay to other trees. In old growth stands, these decay fungi cause more volume loss than all other diseases combined.

Two types of decay occur, depending on how physical and chemical properties of wood are altered. Brown rots destroy cellulose, leaving the brown lignin that usually cracks into cubical blocks; white rots destroy both cellulose and lignin, leaving only a bleached residue in late stages of decay.

Two stages describe the degree of wood decay. In the earliest or incipient stage, the predominant feature is discoloration or stain without an accompanying strength loss; the advanced stage is characterized by both cell breakdown and strength loss. Occasionally an intermediate stage occurs between the two stages. All stages are often present, the incipient stage at the advancing margins of a zone of decay and the more advanced stages near the center.

Decays may be classed as sap rots or heart rots, but this does not always separate decays caused by different fungi. Most fungi normally decaying sapwood are also capable of attacking heartwood, and most fungi normally decaying heartwood attack sapwood in dead trees.

Absence of fruiting bodies does not mean that a tree is sound. Some fungi rarely produce conks on living trees, although fruiting may be prolific after the tree dies. Presence of conks on some trees is a reliable indicator of the amount of cull to be expected.

Although many decays are restricted to a few principal tree species, all native trees are subject to decay by one or more fungi.

Some of the more common stem and butt decays in Montana are:

1. Brown, stringy rot of true firs and hemlock, caused by the Indian paint fungus, Echinodontium tinctorium.
2. Red ring rot of western larch, the pines, spruce, and Douglas-fir, caused by Tomes pini.
3. Brown trunk rot of western larch, Douglas-fir, and ponderosa pine, caused by the guinine fungus, Tomes laricis.
4. Brown, crumbly rot of all dead conifers, caused by the red belt fungus, Tomes pinicola.
5. Brown cubical butt rot of Douglas-fir, true firs, spruce, and hemlock.
6. Red heart rot of all living conifers, caused by the bleeding fungus, Stereum sanguinolentum.

## Management Suggestions to Reduce Stem and Butt Decay Impact

Young trees are practically free from decay, but loss increases with advancing age. Decay cannot start until heartwood formation begins. From that time on trees are liable to decay, but it is usually many years later before decay of consequence is evident. Just when the increase in decay becomes serious determines the maximum age at which the stand should be cut to avoid economic losses. This limiting age has been termed the "pathological" rotation. Under managed conditions, we expect the age at which decay causes consequential loss will be well beyond the actual rotation set by other considerations. Some exceptions will occur; advanced decay may be found occasionally in 20-year-old trees.

Open wounds are avenues for entrance of decay into heartwood; the wound must be completely grown over before the tree is no longer exposed to infection. Wounds are caused by many agents, some of which can be controlled. Logging commonly wounds trees so that serious decay may result, particularly in thin-barked species such as hemlock and true firs.

Reducing injuries to residuals during thinnings or partial cuts will help reduce the impact of decay fungi. In thin-barked species, this may mean special care in laying out skid trails and limiting the type of equipment. During partial cutting, remove all trees with decay indicators, large fire scars and logging wounds. Consider the "pathological" rotation along with other factors when developing stand prescriptions.

## Root Diseases

Root disease complexes are frequently caused by two or more different fungi acting together. Root disease diagnosis is based on:

1. Continuing mortality in expanding centers. Chronic tree death over a long period is often attributed to insects; but this mortality is often caused by root disease. Root pathogens tend to kill a few trees each year, resulting in currently fading trees on the margin and older mortality toward the center. Bark beetle-caused mortality alone usually tends to be more sporadic.

2. Crown symptoms of living trees. Crowns are often chlorotic and show thinning from the bottom up and the inside out, with reduced shoot growth. Diseased trees may also produce stress cone crops. Young trees are killed more quickly than older ones, and crown symptoms may not be as pronounced on younger trees. Crown symptoms are relative and comparisons should be made with adjacent healthy trees.

3. Symptoms and signs in roots and root crowns. Trees often show basal resin flow, wood discoloration and decay, and presence of fungus tissue. Not all diseased trees show root crown symptoms; several trees in and around suspected disease centers should be checked. Declining trees are more reliable for checking because dead trees are usually invaded by secondary fungi which may mask any evidence of pathogens. Collection of samples for laboratory analysis may be necessary for identification of some root pathogens.

## Root Disease Management Implications and Strategies

Economic losses from root diseases are a function of management objectives. In areas where big game habitat is desirable, openings created by root diseases may provide extensive browse and be beneficial. In developed recreation areas, root diseases may reduce site desirability by killing trees and making them hazardous to people and property. In commercial forest stands, root diseases affect yields by killing trees and causing growth loss. Forest land may also be rendered nonproductive when disease centers regenerate with susceptible tree species that are subsequently killed before they reach merchantability.

Treatment options for dealing with root diseases in developed sites are:

1. Sites proposed for development should be carefully examined and root disease problem areas avoided.

2. All trees in developed sites should be inspected periodically. Those suspected to be root diseased should be monitored and removed if they become hazardous.

3. Susceptible trees should be replaced with more disease tolerant species to maintain quality of developed sites.

Management options to deal with root diseases in commercial timber stands include:

1. Do nothing. Mortality will probably continue as disease centers enlarge. Centers will become occupied with brush and some trees; productivity may be lost if centers regenerate with susceptible trees and mortality continues.

2. Salvage dead and dying trees. Although rates of disease spread and tree mortality will probably not be reduced, recovery of potentially lost wood will be possible.

3. Regenerate with site-suited, less susceptible species. Not all species are equally susceptible to root pathogens. Many young stands can be grown to merchantable size if disease tolerant species are favored.

4. Experimentation in stopping marginal spread of root disease centers and reclaiming those sites for future production has been tried in several locations. Procedures include

removal of all trees and stumps for a 1-to 2-chain radius around well defined root disease centers. Stumps and major roots are then removed from centers if sites are to be regenerated with susceptible species and returned to productivity.

5. Young stands with large amounts of root diseased should not be thinned as early or as heavily as uninfected stands.

Some Examples of Root Disease

The more common root diseases in Montana include Armillaria root rot, red brown butt rot, black stain root disease, and annosus root rot. These differ enough in their importance and possible management strategies that we will consider them individually.

ARMILLARIA ROOT ROT, caused by *Armillaria mellea*, affects all conifer species in Montana. It is the most common and most widely distributed root disease in the state. Most large disease centers occur in true fir and Douglas-fir habitat types. Trees infected with *A. mellea* show typical crown symptoms. The fungus produces large white mycelial fans under the bark and causes heavy resin flow at the root collar. Other signs include rhizomorphs (shoestring-like bundles of mycelium) on the outside of infected roots and honey-colored mushrooms at the base of infected trees in late summer or early autumn. *A. mellae* commonly invades stressed trees or those infected with other root pathogens. The fungus survives readily on dead stumps and roots in the soil. It spreads from these to the roots of live trees either through direct root contact or by rhizomorphs. From infected roots, *A. mellae* colonizes the root collar, kills the cambium, and eventually girdles the tree. Infected trees are often attacked by bark beetles.

Although *A. mellea* has a wide host range, usually only a few species are affected within a particular disease center. For example, where Douglas-fir and grand fir are infected, western larch and the pines may not be, and will persist in disease centers. Least affected species should therefore be favored in silvicultural treatments. In young stands with extensive scattered mortality, thinnings should be delayed because losses will probably continue as trees approach merchantable size.

RED BROWN BUTT ROT, caused by *Phaeolus schweinitzii*, occurs mainly on Douglas-fir, grand fir, and ponderosa and western white pines. Most other conifers may also become infected. Trees infected with *P. schweinitzii* seldom show root disease crown symptoms. Root symptoms become detectable only after extensive decay of supporting roots has occurred and caused windthrow. The pathogen also predisposes trees to bark beetles. Infection occurs primarily through small roots and occasionally through basal wounds. Spread is probably by fungus growth through the duff. The fungus occasionally produces annual conks at the base of severely infected trees and on downed timber. Conks have a reddish-brown upper surface with a velvety texture and concentric rings. Most damage occurs in stands more then 80 years old. This fungus is often associated with other root pathogens, particularly Armillaria mellea, forming root disease complexes. P. schweinitzii may be common in Douglas-fir stands throughout Montana.

Stand entries should be reduced and damage to residual trees avoided. Pines and western larch should be favored when possible and rotations should be no more than 90 years. Thinnings should be delayed because the disease may reduce stocking to levels where thinning is not needed.

BLACK STAIN ROOT DISEASE, caused by Ceratocuptis wageneri, occurs on Douglas-fir and lodgepole, ponderosa, and eastern white pine. Douglas-fir is probably the most common host. Trees with black stain show typical wilt symptoms: foliage becomes thin and chlorotic, and needles drop prematurely. Sapwood in roots or the root collar has streaks of brown to black stain parallel to the annual rings. Stain seldom extends more than a few feet above the root collar. Extensive resin soaking is usually present around stained wood. The pathogen infects sapwood of the roots, root crown, but is restricted to small roots. These trees are often infected with Armillaria mellea which does colonize the root collar. In established infection centers, the fungus spreads from tree to tree by root contacts. Bark beetles are intimately associated with the fungus; infected trees are almost always attacked. The fungus produces spores in sticky mucilagenous heads at the tip of small structures which line the inside of beetle galleries. As beetles emerge, they pick up spores on their bodies and may inoculate new trees during attack. Black stain has been found at many locations and may be common throughout the state.

Specific guidelines to control black stain root disease have not been developed. Where the disease occurs, least effected species should be favored. Stand conditions conducive to initial infection are unknown; but tree stress, poor site adaptation and other factors might contribute to stand or tree susceptibility.

ANNOSUS ROOT ROT, caused by Fomes annosus, occurs primarily on ponderosa pine, but is also infects the true firs, Douglas-fir, and western redcedar. It also causes a butt rot in western hemlock. The fungus has been found on both old growth and young ponderosa pine regeneration in western Montana. Trees with annosus root rot show typical root disease crown symptoms. Incipient decay appears as yellow-brown to red-brown stain. Advanced decay is characterized by a white stringy or spongy mass containing many small black flecks running parallel to the grain. Conks are perennial, woody to leathery, with the upper surface dark brown to black, and the lower surface white to cream. Conks are produced deep within infected stumps or at the base of recently killed trees under the litter layer. F. annosus becomes established in healthy stands by infection of freshly cut stump surfaces by airborne spores. The fungus colonizes the stump and its root system and spreads to adjacent healthy trees by root contacts. The pathogen colonizes the cambium at the root collar and girdles the tree. Root decay occurs after tree death. The disease cycle may vary somewhat in true firs and western hemlock where the fungus often decays older trees for many years before killing the tree.

Control of annosus root rot is accomplished by protecting freshly cut stump surfaces from infection. Chemicals such as sodium borate (borax), and biological agents such as competing saprophytic fungi work well.

## Chemicals in Forest Pathology

Although fungicides are commonly used to control plant diseases, in general, their application in control of tree diseases is limited, except for nursery and urban problems, because of the cost.

Chemical control methods rely mainly on treatment before the disease becomes established, either by eradicating the pest from the area (soil fumigation) or by protecting the tree with a chemical barrier (foliage sprays). Once a tree is infected, it is practically impossible to cure it with chemicals. The nurseryman or arborist must be prepared to apply chemical controls either just before or at the first appearance of the disease.

# SECTION IV

# VERTEBRATE PESTS

# CHAPTER XIII

## Introduction

Certain wildlife species can cause damage to forestry plantings or restocking programs either by consuming conifer seeds or by damaging trees or young seedlings. Wildlife that can become pests include some of Montana's more unique species such as deer and elk, porcupines, beaver, rabbits and hares, woodrats, deer mice, voles, shrews, pocket gophers and ground squirrels.

As is true of all kinds of pest control, identification of the damaging species is important. In forestry situations where managers often deal with wildlife that have value economically, ecologically and aesthetically this is especially critical. Identification of problem species prior to undertaking a silvicultural project may help managers anticipate and undertake preventative methods to control damage. An evaluation of the available alternative control methods will help in the choice of methods that are the most effective and safest. In conducting pest management operations, it is recommended that managers contact the U.S. Forest Service, the Montana Department of Agriculture Rodent Specialists, or the County Extension Agents for assistance. Where game animals or furbearers such as beaver or muskrats are causing damage, biologists in the Montana Department of Fish, Wildlife and Parks should be consulted prior to undertaking a control program.

# CHAPTER XIV

## COMMON VERTEBRATE PESTS - BIOLOGY AND CONTROL

The following discussion is a brief introduction to the most important vertebrate pests of forestry plantings in Montana. No attempt has been made to include all mammals that can be pests. In localized situations, or as silvicultural methods change, unique pest problems may be encountered.

### Deer Mice (*Peromyscus maniculatus*) and Voles (*Microtus* spp.)

These small mammals are important primarily because of the damage caused by consumption and removal of conifer seeds. This group, in addition to deer mice, red-backed voles, and meadow and mountain voles includes western jumping mice (*Zapus princeps*), and shrews (*Sorex* spp.). However, deer mice are the most serious pests of conifer seeds. One researcher estimated that a deer mouse could consume 250-350 Douglas-fir seeds per day and that, in most planting areas, deer mice and other seed eating species were sufficiently numerous to nullify seeding efforts. In addition to removing planted conifer seeds, their harvest of naturally dispersed seeds is also significant. Other kinds of damage caused by small mammals are the debarking and girdling of trunks and limbs of small trees. This is caused primarily by voles (*Microtus* spp.) and usually occurs during the winter below the snow.

Several non-chemical methods of control may be useful in controlling mice. The elimination of thick grass cover is especially useful to prevent damage to young treey by voles. Grassy vegetation can be removed by hand, with cultivating equipment, or with selective herbicides. Maintaining a grass free area within 3 feet of trees is important. This practice has limitations in Montana because of the cover provided for mice by snow during the winter.

Mouse guards around the bases of trees provide a mechanical barrier that lasts for several years. Commercial products are available, or 1/4 inch mesh hardware cloth can be used. This should be wrapped closely around the tree trunk, extend 3 inches into the soil and at least 20 inches above the soil surface.

Trapping can be used to effectively eliminate mice in small areas but may be impractical on large plantations because of the time and effort involved. Wooden snap traps, set at right angles to runways, and baited with peanut butter or dried fruits will be effective.

Chemical controls for these small mammals have traditionally involved the use of acutely toxic rodenticides such as endrin, strychnine, compound 1080, thallium sulfate and zinc phosphide. Currently, strychnine and zinc phosphide on grain bait are registered in Montana for controlling mice in forestry situations. Both products are acutely toxic to other animals and should, therefore, be used discriminately to avoid unintentional poisoning of wildlife or domestic animals. Anticoagulant rodenticides, not yet registered in Montana for forest rodent control, offer another potential alternative that may be generally safer to nontarget wildlife in the near future.

Because of the potential of small mammals to repopulate poisoned areas quickly, some researchers have concluded that the use of rodenticides was inadequate to provide long term control. Studies have shown that repopulation of a poisoned area can begin within 2 weeks and that mouse populations can return to normal in 3-5 months. Populations often rebound to higher than pre-treatment levels on treated areas. Baiting a peripheral strip or buffer zone may delay the onset of reinvasion of treated areas. Repeated applications of bait may keep populations low but may not be desirable from economic or environmental viewpoints. Evidence indicates that poison bait programs to control seed eating mammals have a good chance of failure, especially in conifer seeding programs.

Very few alternative chemical measures have proven effective for controlling small mammals. On small acreages, the use of bait feeders can help to ensure a constant supply of bait. Some initial work has been done with the concept of shelter seeding in which seeds are protected from the elements by a clear plastic inverted cup. It seems reasonable that this method can be modified to give protection from seed eating mammals.

The chlorinated hydrocarbon, endrin, has been used widely to protect conifer seeds from small seed eating mammals. Seeds coated individually with sublethal doses of endrin cause an aversive reaction and small mammals are repelled from further seed consumption. This method may be among the most effective for protection of conifer seeds but does have inherent problems, both in effectiveness and environmentally. Even though resident mice, by receiving repeated sublethal doses, may be repelled from further consumption, a constant attrition of seeds can continue due to mouse population turnovers and immigration of new individuals into treated areas. Endrin is also acutely toxic to invertebrates, birds, mammals and fish, and undergoes slow degradation once applied. Depending on environmental conditions, endrin may persist in soils for long periods and may enter and be transferred in food chains. In areas of heavy use, small mammal populations have also developed resistance to endrin. Finally, endrin does reduce seed germination rates by up to 20 percent. At this time, endrin is not registered in Montana for use on conifer seeds.

### Ground Squirrels (*Spermophilus* spp.)

In the forestry areas of northwestern Montana, Columbian ground squirrels (*Spermophilus columbianus*) may occasionally consume conifer seeds even though these are not the preferred food. In Montana, baits containing strychnine, zinc phosphide and diphacinone are registered for ground squirrel control. These products are acutely toxic to most wildlife and humans so appropriate safety precautions should be taken prior to and during use. In localized situations, gas cartridges (burrow fumigants) can provide good control of ground squirrels, but are quite time consuming and expensive on large populations. For more details concerning biology and control of Columbian ground squirrels, managers may consult either the "Vertebrate Pest Training Manual" or the pamphlet "The Columbian Ground Squirrel - Its Biology and Control". Both are available from the Montana Department of Agriculture.

### Northern Pocket Gophers (*Thomomys talpoides*)

In forestry situations pocket gophers may damage conifer seedlings by consuming roots and tops. In Montana, strychnine grain baits and gas cartridges (burrow fumigants) are registered to control pocket gophers. Strychnine baits can be applied with the aid of an implement-drawn mechanical burrow builder. The burrow builder creates an artificial burrow and drops toxic bait periodically inside the burrow. Pocket gophers intersect and occupy these burrows and consume the treated bait. Burrow builders work most effectively in heavy or fine soils that will hold the shape of the artificial burrow. In rugged terrain, dry conditions, or where granular soils preclude the formation of artificial burrows, hand baiting is effective. Trapping can be an effective control method in small areas.

Habitat manipulation using mechanical scarification of topsoil, application of herbicides, or other methods to remove ground cover may help reduce pocket gopher populations to levels more easily managed. Although sound in principle (removal of food supply), these methods have not been adequately demonstrated yet.

Managers wishing additional information on pocket gopher biology and control can consult the "Vertebrate Pest Training Manual" or "Pocket Gopher Control Techniques", both available from the Montana Department of Agriculture. Another excellent source of information on biology and control is "Pocket Gophers and Colorado Mountain Rangeland" available from the Colorado State University Experiment Station.

### Porcupines (Erethizon dorsatum)

These unique, rather solitary animals can become serious pests in conifers. Their food consists of a variety of plants, but in the fall and during drought the inner bark and leaves of conifers are preferred. Trees that have been fed on may be partially or completely girdled, often near the top, resulting in a spike-topped tree useless for commercial purposes. Small seedlings can be completely consumed.

Because of their solitary, infrequent nature, shooting or trapping are probably the simplest and most effective methods for removing offending porcupines. In Montana, strychnine in salt blocks is registered for porcupine control. Blocks can be nailed to trees or placed in bait stations (cubbies) near porcupine travel routes. Certain preventative measures are necessary in using salt blocks because of their attractiveness to domestic animals and other wildlife. In trees, blocks should be nailed 10 feet or more off the ground. In cubbies or bait stations, blocks should be securely fastened well inside, and the bait station immobilized on the ground. Bait stations and blocks in trees should be identified by signs containing the word "POISON", and should be placed in areas not frequented by or visible to the public. Unused blocks should be removed when no longer needed.

### Deer (Odocoileus spp.) and Elk (Cervus elaphus)

Browsing by mule deer, white-tailed deer and elk may cause significant damage to terminal and lateral shoots, buds and foliage. In severe instances, suppression of growth or production of shrubby, highly branched trees is the result of over browsing. Other injuries to trees and seedlings caused by big game include trampling, pulling small seedlings and rubbing (antler polishing). These injuries are of minor importance compared to the economic effects that can occur from browsing.

Toxic chemicals are not registered for controlling damage of big game. Several chemical repellents (thiram, ammonium soaps) are registered in Montana for controlling feeding by deer. Mechanical barriers such as fencing may provide a long term solution in private nurseries. Temporary relief can be obtained by hazing or by using acetylene cannons that create periodic explosions and frighten deer. For severe problems managers should contact the Montana Department of Fish, Wildlife and Parks.

### Snowshoe Hares (Lepus americanus) and Mountain Cottontails (Sylvilagus nuttalli)

The foliage of coniferous trees forms a part of the diet of snowshoe hares and cottontails. In areas where damage by these species can be anticipated, damage control measures should be instituted prior to planting. In Montana, thiram is registered as a rabbit repellent to treat trees before planting. Cultural methods that eliminate brushy ground cover, the habitat of snowshoe hares and cottontails, will reduce their populations. Trapping or shooting may be effective in cases where numbers are small. Mechanical barriers provide long term protection for small trees. Commercial products are available, or 1/4 inch mesh hardware cloth set around young trees will be effective. This should extend 3 inches into the ground and at least 20 inches above the soil surface. In Montana, acute toxicants are not currently registered for control of hares or cottontails.

### Woodrats (Neotoma cinerea)

Woodrats feed on twigs, shoots and bark and may cause damage by stripping bark from older trees or by feeding on branches and foliage of younger trees. Populations can become numerous and in such instances woodrats will consume conifer seeds. They will establish residences in rocky ledges, pine trees, or abandoned cabins and their accumulations of sticks, bones and other debris are familiar to most outdoor persons.

Rodenticides are not currently registered in Montana for controllings woodrats, although in some states acute toxicants have been effective in controlling damage. Silvicultural practices that remove dense tree or brush stands and logging debris may be as effective as poisoning programs in maintaining low population levels. Woodrats are easily trapped in snap or live traps using dried fruits or nuts as baits. Where offending individuals can be located, shooting is an adequate method of control.

## Others

At times other wildlife species such as beaver, muskrats and bears may cause damage on a localized basis. In these instances assistance can be sought from animal control professionals or from local biologists.